THE POPULAR SCIENCE MONTHLY

THE POPULAR SCIENCE MONTHLY

EDITED BY

J. McKEEN CATTELL

VOL. LXV

MAY TO OCTOBER, 1904

NEW YORK
THE SCIENCE PRESS
1904

PRESS OF
THE NEW ERA PRINTING COMPANY
LANCASTER, PA.

THE POPULAR SCIENCE MONTHLY.

MAY, 1904.

THE DEVELOPMENT OF A NEW METHOD OF RESEARCH.*

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IN the fruitful field of astrophysical research there are few opportunities for advance so promising as those afforded by the study of the sun. As the central body of the solar system, maintaining the planets in their orbits by the power of its attraction, and supplying light and heat to the inhabitants of the earth through its radiation, the sun is an object of special interest to every student of nature. Its appeal to the imagination may be said to be threefold in character. In the first place, because of the extraordinary nature of the phenomena on its surface, and the stupendous scale of the eruptive disturbances, which are becoming more and more frequent in the present period of solar activity, the study of the sun for the purpose of gaining an understanding of its structure is in itself a sufficiently attractive object. To some, however, whose interests are aroused more particularly by the problems of chemistry and physics than by those of astronomy, this aspect of solar research may not possess special interest. But through the development of astrophysical methods, it is precisely to the physicist and the chemist that the sun should make a special appeal. For the solar observer may be the spectator of physical and chemical experiments on a scale far transcending any that can ever be performed in the laboratory. In this enormous crucible, heated to temperatures greatly exceeding those attainable by artificial means, immense masses of luminous vapor, including most of the elements known on the earth and many not yet discovered here, may be seen

* Address delivered on November 23, 1903, before the University of Chicago Chapter of the Society of Sigma Xi.

undergoing changes and transformations well calculated to assist in the explanation of problems which the laboratory can not solve.

But to the philosopher and the student of nature as a whole, the sun finds its highest interest in its relationship to the great problem of stellar evolution. For the central body of our system is a star, resembling in the closest way many of the stars of the sidereal universe, but possessing the unique distinction of comparative proximity to the earth. Even in the most powerful telescopes, all the other stars appear as minute points of light, which every improvement in telescope construction tends to render more minute and microscopic, so great is the distance of these stars from the observer on the earth. We have no reason to believe that telescopes will ever be constructed so powerful as to magnify a stellar image into an actual disk. With our present knowledge we therefore may not expect that the great flames and other evidences of eruptive phenomena, which we believe from inference to be as characteristic of the stars as of the sun, will ever become visible. We must therefore depend for a knowledge of such phenomena upon the one star whose surface can be studied in detail. Armed with this knowledge, we may trace out with the spectroscope successive steps in the development of a star, from its origin in a nebula, on through the earlier stages typified by such stars as Sirius, to the condition attained in the sun. In this object we seem to observe the culmination of stellar life. For evidences of decay we must investigate the red stars, in which the radiation of heat throughout immense periods of time has resulted in cooling toward the point of final extinction. Thus we may untangle the great problem of stellar evolution, and at the same time build up a complete history of the sun, learning what it has been, what it is and what it will become.

Prior to the middle of the nineteenth century, at periods of total eclipse, when the dark body of the moon cuts off completely the bright light of the solar disk, red flames were observed at many points on the moon's circumference. At first their nature was so little understood that they were described by some observers as lunar mountains. But in 1868, through the use of the spectroscope, their true gaseous nature and their connection with the sun became known. It was found that immense masses of hydrogen and helium gas rise from a sea of flame (the chromosphere) which completely envelops the sun, and that these 'prominences' sometimes attain elevations of hundreds of thousands of miles.

The rarity and brief duration of total eclipses would have limited greatly our knowledge of the prominences, had not a method been devised by which they can be observed on any clear day in spite of the glare of our atmosphere around the sun. The instrument which permits this result to be accomplished is the spectroscope, used in con-

junction with the telescope. The principle of the method is simple and easily understood. The white light of the sky, when passed through a spectroscope, is drawn out into a long rainbow band, and thereby enormously reduced in intensity. The light of the prominences, on the contrary, is concentrated in the radiations characteristic of hydrogen and helium gas, and the great dispersing power of the spectroscope merely separates more and more widely the colored images which correspond to these radiations, without greatly reducing their intensity. With the spectroscope they therefore become visible, since their images are brighter than the highly dispersed background of skylight on which they lie.

Armed with this method, observers in various parts of the world have systematically observed the forms of the solar flames on every clear day, giving us a continuous record of these phenomena now extending back for more than thirty years. From a study of this record many conclusions regarding the nature of the flames and their bearing on the question of the solar constitution, have already been reached. But the process of observation is not only slow and painstaking; it is also subject to the errors and uncertainties that attend the hand delineation of every object, seen through a fluctuating atmosphere, under unfavorable conditions. It was principally in the hope of simplifying this process, and of rendering it more rapid and more accurate, that the spectroheliograph was devised by the writer in 1889.

The principle of this instrument is very simple. Its object is to build up on a photographic plate a picture of the solar flames, by recording side by side images of the bright spectral lines which characterize the luminous gases. To accomplish this an image of the sun is formed by the telescope on the slit of a spectroscope. The light of the sun, after transmission through the spectroscope, is spread out into a long band of color, crossed by lines representing the various elements. At points where the slit of the spectroscope extends out beyond the sun's edge across a gaseous prominence, the bright lines of hydrogen and helium may be seen extending from the base of the prominence to its highest point. If a series of images of such a line, corresponding to different positions of the slit on the prominence, were recorded side by side on a photographic plate, it is obvious that they would give a representation of the form of the prominence itself. To produce such an effect it is only necessary to cause the solar image to move at a uniform rate across the first slit of the spectroscope and then, with the aid of a second slit, which takes the place of the eyepiece of the spectroscope, to isolate one of the lines, permitting the light from this line, and from no other portion of the spectrum, to pass through the second slit to a photographic plate. If the plate is moved at the speed with which the solar image passes across the

first slit, an image of the prominence will be recorded upon the plate. The principle of the instrument thus lies in photographing the solar

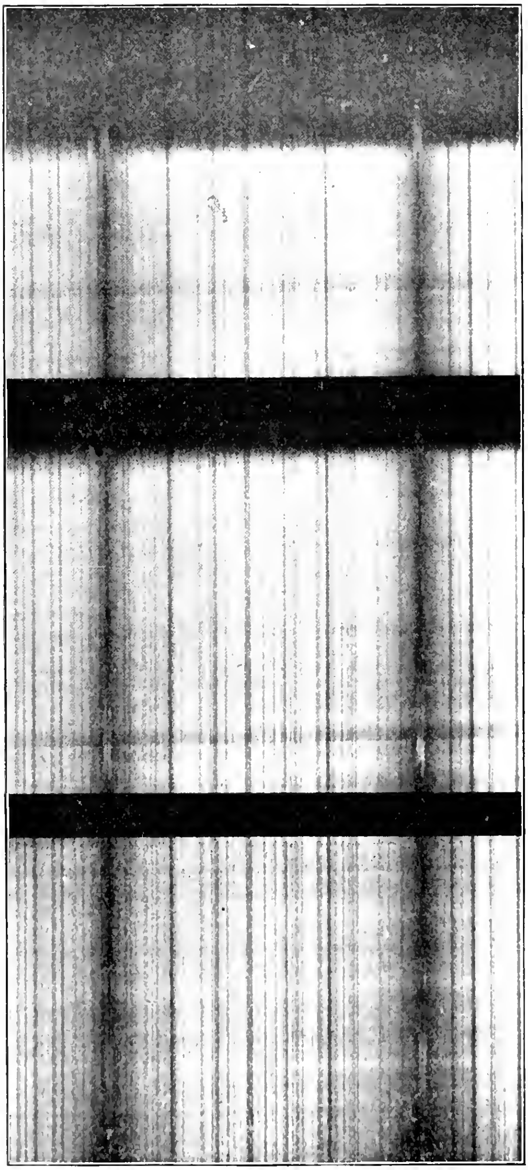


FIG. 1. — *H* AND *K* LINES ON THE DISK, IN THE CHROMOSPHERE, AND IN A PROMINENCE (*a*).

flame through a narrow slit, from which all light is excluded except that which is characteristic of the prominence itself.

This method, when tried by the writer at the Harvard Observatory in 1890, proved unsuccessful. The lack of success was partly due to the fact that a line of hydrogen was employed. This line, though fairly suitable for the photography of prominences with the perfected spectroheliograph of the present day, was too faint for successful use

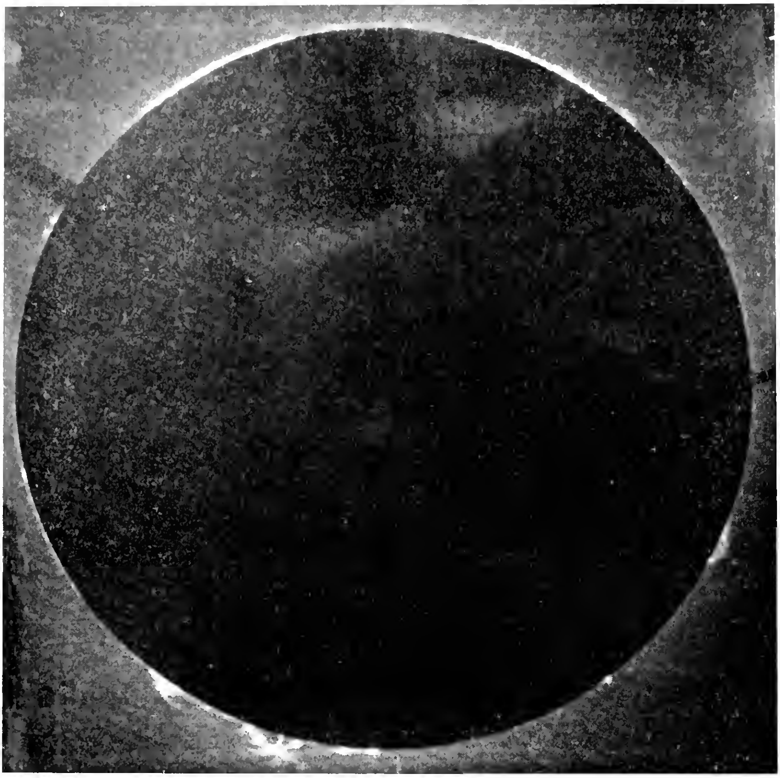


FIG. 2. THE SOLAR CHROMOSPHERE AND PROMINENCES.

amidst the difficulties which surrounded the first experiments. Accordingly, when the work was resumed a year later at the Kenwood Observatory in Chicago, an attempt was first made, through a photographic investigation of the violet and ultra-violet regions of the prominence spectrum, to discover other lines better fitted for future experiments. In the extreme violet region, in the midst of two broad dark bands which form the most striking feature of the solar spectrum, two bright lines (*H* and *K*) were found which were attributed to the vapor of calcium. They had previously been seen visually in the prominences, but on account of the insensitiveness of the eye for light of this color, their true importance had hardly been realized. A careful study soon showed them to be present in every prominence observed, at eleva-

tions above the solar surface equaling or exceeding those attained by hydrogen itself (Fig. 1, *a*). Their suitability for the purpose of prominence photography is due to several causes, among which may be mentioned their great brilliancy, their presence at the center of broad dark bands which greatly diminish the brightness of the sky spectrum, and the comparatively high sensitiveness of photographic plates for light of this color.

While fairly efficient from an optical point of view, the spectroheliograph of the preceding year had possessed many mechanical defects. In a new instrument, devised for use with the twelve-inch Kenwood telescope, these were overcome, and means of securing the necessary conditions of the experiment were provided. The first trials

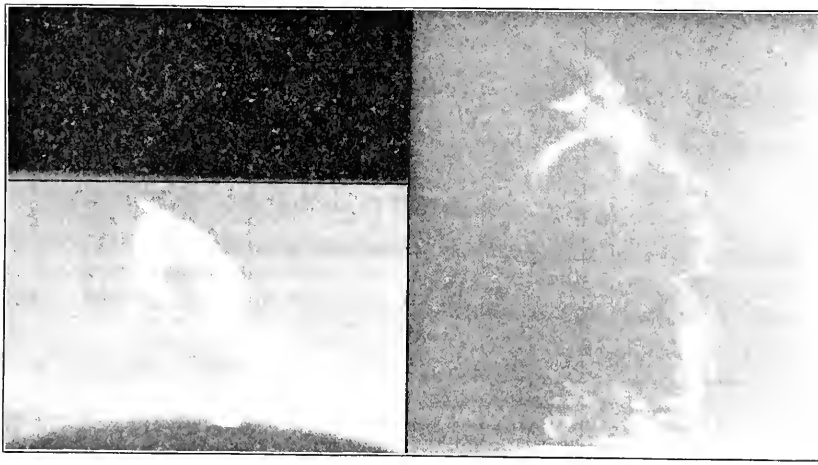


FIG. 3. ERUPTIVE PROMINENCE OF MARCH 25, 1895. *a*, 10h 34m. HEIGHT, 135,000 MILES. *b*, 10h 58m. HEIGHT, 281,000 MILES.

of the instrument, made in January, 1892, were entirely successful, and the chromosphere and prominences surrounding the sun's disk were easily and rapidly recorded (Fig. 2). The details of their structure were shown with the sharpness and precision characteristic of the best eclipse photographs. And the opportunity for making such records, previously limited to the brief duration, never exceeding seven minutes, of a total solar eclipse, was at once indefinitely extended. Thus it became possible to study photographically the slowly varying forms of the quiescent, cloud-like prominences, and, to particular advantage, the rapid changes of such a violent eruption as is illustrated in Fig. 3.

But even before this primary purpose of the work had been accomplished, the possibility of making another and much more important application of the instrument had presented itself. A photographic

study of the spectrum of various portions of the sun's surface had shown the existence at many points of great regions of calcium vapor, luminous enough to render their existence evident through the production of bright *H* and *K* lines on the solar disk (Fig. 1, *b* and *c*). Some of these calcium regions had indeed been known to exist through the visual observations of Professor Young, who had observed the bright lines in the vicinity of sun-spots. But the vast extent of the calcium regions, and the characteristic forms of the phenomena, could not be ascertained by such means. What was required was such a

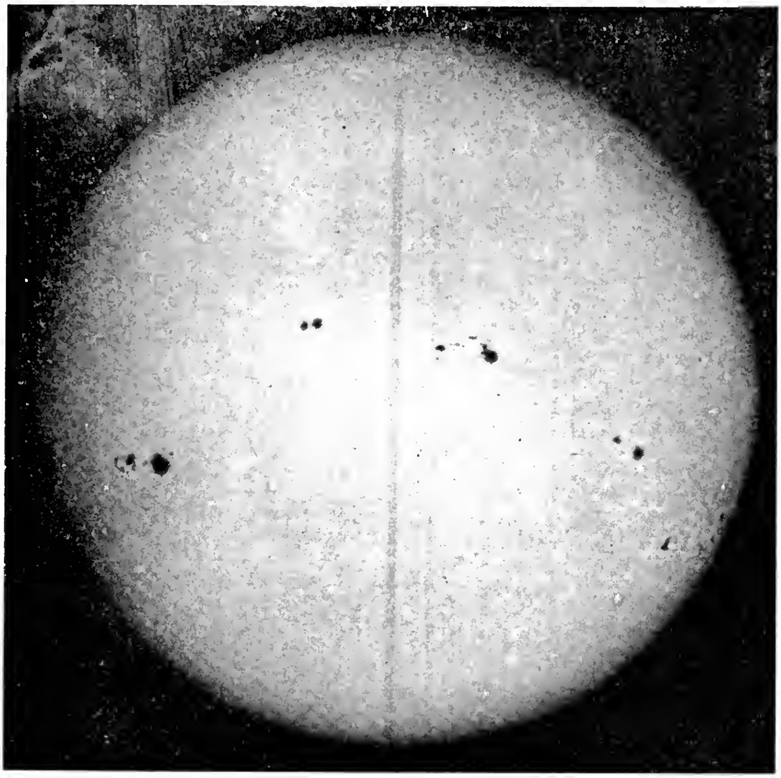


FIG. 4. ORDINARY PHOTOGRAPH OF THE SUN.

representation of the solar disk as the spectroheliograph had been designed to give in the case of the prominences. From a consideration of the results obtained in the spectroscopic study of the disk, it appeared probable that an important application of the spectroheliograph might be made in this new direction.

Before describing this second application of the instrument, it may be well to call attention to the appearance of the sun when seen with a telescope, or when photographed in the ordinary manner, without a

spectroheliograph. Such a photograph is reproduced in Fig. 4. Its most conspicuous features are the numerous dark spots scattered over the sun's surface; these are the well known sun-spots. Near the edge of the sun there may be seen certain bright regions, which are known as faculæ. The calcium regions above referred to are usually associated with the faculæ, but they lie above them, and they give no trace of their existence on ordinary photographs, like the one in Fig. 4, or to the eye when observing the sun through a telescope.

The results of the first experiments, which were made at the beginning of 1892, were such as to justify fully the expectations that had been entertained. It was at once found possible to record the forms, not only of the brilliant clouds of calcium vapor associated with the faculæ, and occurring in the vicinity of sun-spots, but also of a reticulated structure extending over the entire surface of the sun. The earliest applications of the method were made in the study of the great sun-spot of February, 1892, which, through the great scale of the phenomena it exhibited, and the rapid changes that resulted from its exceptional activity, afforded the very conditions required to bring out the peculiar advantages of the spectroheliograph. In the systematic use of the instrument continued at the Kenwood Observatory through the following years, a great variety of solar phenomena were recorded, and the changes which they underwent from day to day—sometimes, in the more violent eruptions, from minute to minute—were registered in permanent form for careful study. During this period, which ended with the transfer of the Kenwood instruments to the Yerkes Observatory, over 3,000 photographs of solar phenomena were secured. From a systematic study of these negatives, in the course of which the heliographic latitude and longitude of the calcium regions in many parts of the sun's disk were measured from day to day, a new determination of the rate of the solar rotation in various latitudes has been made. This shows that the calcium regions, like the sun-spots, complete a rotation in much shorter time at the solar equator than at points nearer the poles. In other words, the sun does not rotate as a solid body would do, but rather like a ball of vapor, subject to laws which are not yet understood.

In this first period of its career the spectroheliograph had therefore permitted the accomplishment of two principal objects. It had provided a simple and accurate means of photographing the solar prominences in full sunlight, which gave results hardly inferior to those obtained during the brief moments of a total eclipse. It had also given a means of recording a new class of phenomena, known previously to exist only through glimpses of the bright calcium lines in the vicinity of sun-spots, but wholly invisible to observation either visually or on photographs taken by ordinary methods. It was not difficult to see, how-

ever, that the possibilities of the new method were much greater than had been indicated by the work so far accomplished. It seemed certain that our knowledge of the finer details of the calcium clouds would be greatly increased if provision could be made for photographing a much larger solar image with a spectroheliograph of improved design. And

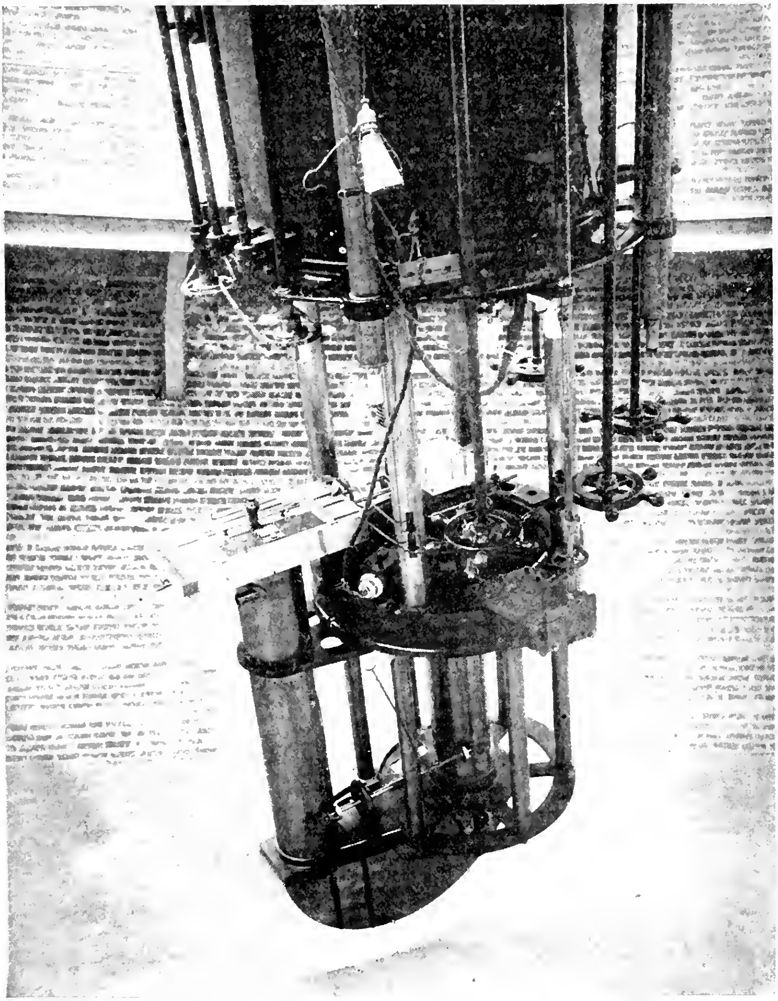


FIG. 5.—THE RUMFORD SPECTROHELIOGRAPH ATTACHED TO THE YERKES TELESCOPE.

it was furthermore evident that other applications of the instrument, involving the use of different spectral lines, and the employment of principles which had not entered in the Kenwood work, might reasonably be hoped for.

The construction of the great forty-inch telescope of the Yerkes

Observatory provided the first requirement of this new work, namely, a large solar image, having a diameter of seven inches as compared with the two-inch image given by the Kenwood telescope. The construction of a spectroheliograph large enough to photograph such an image of the sun involved serious difficulties, but these were finally overcome. The Rumford spectroheliograph, designed to meet the special conditions of the new work, was constructed in the instrument

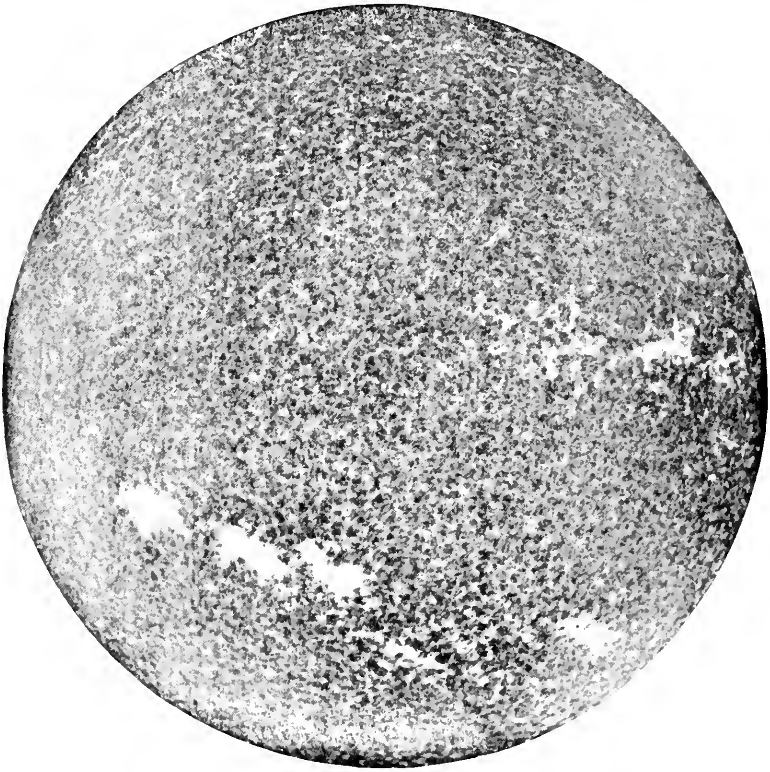


FIG. 6.—THE SUN SHOWING THE CALCIUM FLOCCULI (H_2 LEVEL). 1903, AUGUST 12, 8h 52m. C.S.T.

shop of the Yerkes Observatory, and is now in daily use with the forty-inch telescope (Fig. 5).

In this instrument the solar image is caused to move across the first slit by means of an electric motor, which gives the entire telescope a slow and uniform motion in declination. The sun's light, after passing through the first slit, is rendered parallel by a large lens at the lower end of the collimator tube. The parallel rays from this lens fall upon a silvered glass mirror, from which they are reflected to the first of two prisms, by which they are dispersed into a spectrum.

After passing through the prisms, the light, which has now been deflected through an angle of 180°, falls upon a second large lens at the

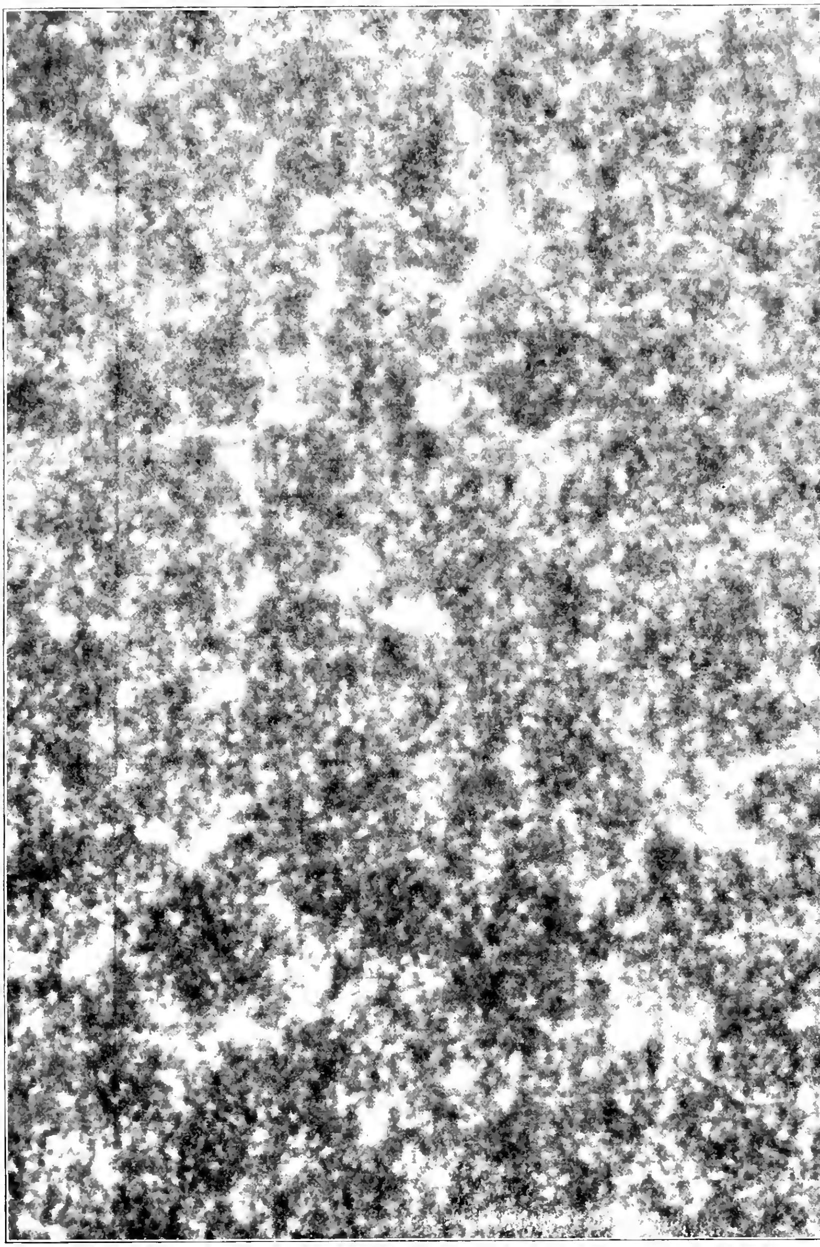


FIG. 7.—MINUTE STRUCTURE OF THE CALCIUM FLOCCULI AT H_2 LEVEL. 1903, SEPTEMBER 22. (Scale: Sun's Diameter 0.890 Meter.)

lower end of the camera tube. This forms an image of the spectrum at the upper end of the tube, where the second slit is placed. Any line in

the spectrum may be made to fall upon this slit by properly adjusting the mirror and prisms. Above the slit, and nearly in contact with it, the photographic plate is mounted in a carriage which runs on tracks at right angles to the length of the slit. The tracks are covered by a light-tight camera box, so that no light can reach the plate except that which passes through the second slit. While the solar image is moving across the first slit, the plate is moved at the same rate across the second slit, by a shaft leading down the tube from the electric motor, and connected, by means of belting, with screws that drive the plate-carriage.

Photographs of the solar disk taken with this instrument under good atmospheric conditions show a multiplicity of fine details of which no trace appears on the Kenwood plates (Fig. 6). The entire surface of the sun is shown by these plates to be dotted over with minute luminous clouds of calcium vapor, separated by dark spaces, and closely resembling in appearance the well-known granulation of the solar photosphere (Fig. 7). A sharp distinction must, however, be drawn between this appearance, which is wholly invisible to the eye at the telescope, and the granulation of the photosphere. In accordance with Langley's view the grains into which the surface of the sun is resolved under good conditions of visual observation are the extremities of columns of vapor rising from the sun's interior. They seem to mark the regions at which convection currents, proceeding from within the sun, bring up highly heated vapors to a height where the temperature becomes low enough to permit them to condense. It might be anticipated that out of the summits of these condensed columns, other vapors, less easily condensed, might continue to rise, and that the granulated appearance obtained with the spectroheliograph may represent the calcium clouds at the summits of these columns. We might indeed go a step further, and imagine the larger and higher calcium clouds to be constituted of similar vaporous columns, passing upward through the chromosphere and perhaps at times extending into the prominences themselves. But without a means of research now to be described, which represents another application of the spectroheliograph, involving a new principle, the true nature of these phenomena could not be ascertained.

Mention has already been made of the luminous faculæ, which are simply regions in the photosphere that rise above the ordinary level. At the edge of the sun their summits lie above the lower and denser part of that absorbing atmosphere which so greatly reduces the sun's light near the limb, and in this region the faculæ may be seen visually. At times they may be traced to considerable distances from the sun's limb, but as a rule they are inconspicuous or wholly invisible toward the central part of the solar disk. The Kenwood experiments had shown

that the calcium vapor usually coincides closely in form and position with the faculæ, and hence the calcium clouds were long spoken of under this name. In the new work at the Yerkes Observatory the distinction between the calcium clouds and the underlying faculæ is so marked that a distinctive name for the vaporous clouds has become necessary. They have therefore been designated *flocculi*, a name chosen without reference to their actual nature, but suggested by the flocculent appearance of the photographs.

In order to analyze these flocculi and to determine their true structure, a method was desired which would permit sections of them at different heights above the photosphere to be cut off, as it were, and

H *K*

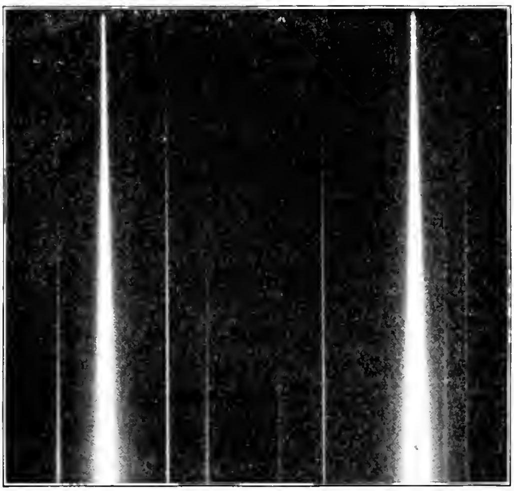


FIG. 8.—*H* AND *K* LINES IN ELECTRIC ARC, SHOWING REVERSALS.

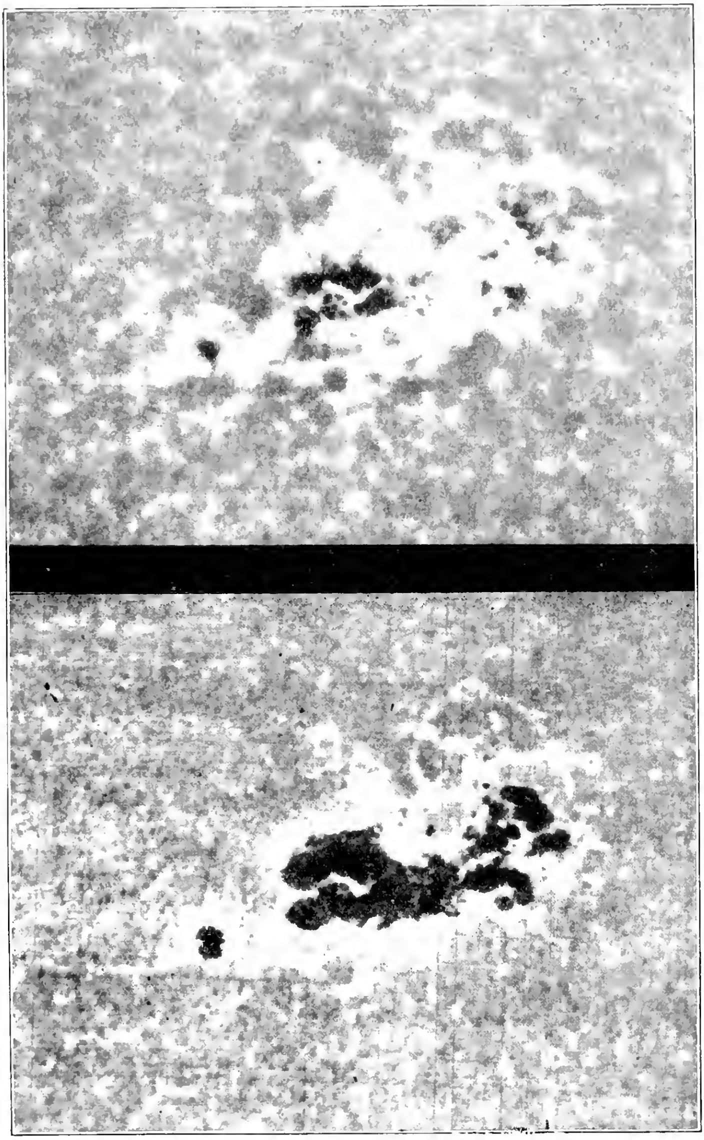
photographed. Fortunately there is a simple means of accomplishing this apparently difficult object. At the base of the flocculi the calcium vapor, just rising from the sun's interior, is comparatively dense. As it passes upward through the flocculi it reaches a region of much lower pressure, and during the ascent it might be expected to expand and therefore to become less dense. Now we know from experiments in the laboratory that dense calcium vapor produces very broad spectral bands, and that as the density of the vapor is decreased these bands narrow down into fine sharp lines (Fig. 8). An examination of the solar spectrum will show that the *H* and *K* lines of calcium give evidence of the occurrence of this substance under widely different densities in the sun. The broad dark bands, which for convenience we designate as H_1 and K_1, are due to the low-lying dense calcium vapor (Fig. 1). At their middle points (over flocculi) are seen two bright

lines, which are much narrower and better defined. These lines, which we designate as H_2 and K_2, are the ones habitually employed in photographing the flocculi with the spectroheliograph. Superposed upon these bright lines are still narrower dark lines, due to the absorption of cooler calcium vapor at higher elevations (H_3, K_3). It will be seen that the evidence of the existence of calcium vapor at various densities in the sun is complete, and that we may here find a way of photographing the vapor at low levels without admitting to the photographic plate any light that comes from the rarer vapors at higher levels. It is simply necessary to set the second slit of the spectroheliograph near the edge of the broad H_1 or K_1 bands, in order to obtain a picture showing only that vapor which is dense enough to produce a band of width sufficient to reach this position of the slit. No light from the rarer vapors above can enter the second slit under these circumstances, since they are incapable of producing a band of the necessary breadth. Light from the denser vapors below will, however, enter the slit. But since it happens, within certain limits, that the vapor grows brighter and also expands as it rises above the photosphere, it seems to follow that a photograph will generally represent a section of the vapor at the level corresponding to the position of the line on the slit, and that little confusion will result from the presence of the denser but less brilliant vapors lying below.

The great sun-spot of October, 1903, afforded an opportunity to try this method in a very satisfactory manner. Sections of the calcium vapor in the neighborhood of this spot-group, corresponding to the two different levels photographed on October 9, are shown in Fig. 9.* The manner in which the vapor at the H_2 level overhangs the edge of the sun-spot is very striking, and thorough study should throw some light on the conditions which exist in such regions. For it is possible, not only to photograph sections of the vapor at various levels, but also to ascertain by the displacement of the H_2 line, as photographed with a powerful spectroscope, the direction and velocity of motion of the vapor which constitutes the flocculus. It is commonly found that the vapor is moving upward at a velocity of about one kilometer per second, though the velocity varies considerably at different

* Although these photographs have been arranged for comparison with the stereoscope, it is to be understood that no stereoscopic effect in the ordinary sense will be obtained in examining them. The purpose of using the stereoscope is simply to allow the images to be superposed, thus permitting them to be seen at the same point in rapid succession by simply moving a card so as to cover alternately the two lenses of the stereoscope. In this way the sun-spot may be examined, first as it appears at the low level of the denser vapor and then as it appears at the higher level of the rarer vapor. Thus the manner in which the calcium flocculi overhang the penumbra, and sometimes the umbra, of spots can be observed.

points and under different conditions. In the near future it is proposed to make a careful systematic study of the motion of the vapor at various regions in the flocculi, in order to determine whether it is gen-



Oct. 9, 3[h] 43[m]. Calcium Flocculi, Middle H_1 Level. Slit at λ 3966. October 9, 3[h] 30[m]. Calcium Flocculi, H_1 Level. Slit at λ 3968.6.

FIG. 9.—THE GREAT SUN-SPOT OF OCTOBER, 1903.

For Comparison with the Stereoscope (see Footnote on p. 191).

erally upward or whether there may be frequent evidence of downward currents or of currents more nearly parallel to the solar surface.

Many photographs show the existence of flocculi remarkable for their great brilliancy. In these regions active eruptions are in

progress. The vapor, rendered highly luminous by intense heat or other causes, is shot out from the sun's interior with great velocity. Consequently there are rapid changes in the forms of these brilliant regions, whereas the more extensive flocculi, which occupy the greater part of the photograph, change slowly, and represent a much less highly disturbed condition of affairs. The brilliant eruptive flocculi always occur in active regions of the solar surface, and doubtless correspond with the eruptive prominences sometimes photographed projecting from the sun's limb. A remarkable instance was recorded on the Kenwood photographs, which showed four successive stages in an eruption of calcium vapor on an enormous scale. A vast cloud thrown out from the sun's interior completely blotted from view a large sun-spot, and spread out in a few minutes so as to cover an area of four hundred millions of square miles.

As already remarked, these eruptive flocculi probably correspond in many instances with the eruptive prominences observed at the sun's edge. But it must not therefore be concluded that the quiescent calcium flocculi correspond with the quiescent, cloud-like prominences. As a matter of fact, we have good evidence for the belief that the flocculi shown in these photographs represent in most instances comparatively low-lying vapors, which, if observed at the sun's edge, would hardly project appreciably above the level of the chromosphere.

In a few cases, represented, perhaps, by the dark calcium flocculi found on certain photographs, the quiescent calcium prominences have been recorded in projection on the disk. But such instances will remain exceptional until a spectroheliograph has been constructed of such high dispersion as to permit photographs to be made with the light of the K_3 line exclusively.

So far we have considered the photography of the sun with the light of the H and K lines of calcium. But it must naturally occur to any one familiar with the solar spectrum that it should be possible to take photographs corresponding to other lines, and thus representing the vapors of other substances. In the solar spectrum some 20,000 lines have been recorded in the great photographic map and catalogue of Rowland, representing almost all the elements known on the earth, and doubtless including many of the radiations of substances which are as yet unknown to terrestrial chemistry. Just as the gas helium was discovered in the sun long before it was found by Ramsay in the laboratory, so we may confidently expect that many other substances represented by lines in the solar spectrum will ultimately be detected on the earth.

Now these lines, like the H_1 and K_1 bands, are dark, and at first sight it might be supposed that for this reason the vapors corresponding with them could not be photographed with the spectroheliograph. But

a moment's consideration will show that no serious difficulty need arise from this cause. For the darkness of the lines is only relative; if they could be seen apart from the bright background of continuous spectrum on which they lie, these lines would shine with great brilliancy. It is thus evident that if all light except that which comes from one of these dark lines can be excluded from the photographic plate by means of the second slit of the spectroheliograph, it should be possible to obtain a photograph showing the distribution of the vapors corresponding with the line in question.

At this point attention should be called to the extreme sensitiveness of the spectroheliograph in recording minute variations in the intensity of a line—variations so slight that no trace of them can be seen in a spectrum photograph showing only the line itself. A well-known physiological action is here concerned, for it is common experience that the eye can not detect minute differences of intensity in various parts of an extremely narrow line, whereas these would become much more conspicuous if the line were widened out into a band of considerable width. The action of the spectroheliograph is to record side by side upon the photographic plate a great number of images of a line which, taken together, build up the form of the region from which the light proceeds. In this way the full benefit of the physiological principle is derived, and very minute differences of intensity between various parts of the solar disk are clearly registered upon the photographic plate.

It is obviously essential in photographing with the dark lines to exclude completely the light from the continuous spectrum on either side of the line employed. The admission of even a small quantity of this light might completely nullify the slight differences of intensity recorded by the aid of the comparatively faint light of the dark line. As the second slit can not be narrowed beyond a certain point, it is evident that for successful photography with the dark lines their width must be increased by dispersion in the spectroheliograph to such a degree as to make them wider than the second slit.

The first successful photographs obtained with dark lines were made with the Rumford spectroheliograph in May, 1903. The lines of hydrogen were chosen for this purpose, on account of their considerable breadth, and because of the prominent part played by this gas in the chromosphere and prominences. In order to secure sufficient width of the lines, the mirror of the spectroheliograph was replaced by a large plane grating having 20,000 lines to the inch. After leaving the grating the diffracted light enters the prisms, where it is still further dispersed before the image of the spectrum is formed upon the second slit. The effect of the prisms is not only to give additional dispersion, but also to reduce the intensity of the diffuse light from the grating

—a most important matter in work of this nature. The hydrogen lines employed were $H\beta$, $H\gamma$ and $H\beta$; $H\delta$ is perhaps the best of these three lines for the purpose.

On developing the first plate we were surprised to find evidences of a mottled structure covering the sun's disk, resembling in a general way the structure of the calcium flocculi, but differing in the important fact that whereas the calcium flocculi are bright those of hydrogen are *dark*. This result was confirmed by subsequent photographs, and it was found that in general the hydrogen flocculi are dark, although in certain disturbed regions bright hydrogen flocculi appear. Some of these are eruptive in character, and correspond closely with the brilliant eruptive calcium flocculi. But in other cases, in regions where no violent eruptive disturbances seem to be present, the hydrogen flocculi sometimes appear to be bright instead of dark. Such regions are usually in the immediate vicinity of active sun-spots, where it is probable that the temperature of the hydrogen vapor is considerably higher than in the surrounding regions. The spectroheliograph thus seems to afford a method of distinguishing between regions of higher and lower temperatures—an additional property which should prove of great value in investigations on the vapors associated with sun-spots. It is possible, of course, that the increased brightness is due not merely to an increase of temperature, but to other causes, perhaps of a chemical or electrical nature, which are not yet understood. But in any event, the method serves to differentiate these regions from others in which these conditions are not fulfilled, and the possibility of making such a differentiation is of value, even if we do not as yet understand the actual cause of the increased brightness.

The comparative darkness of the hydrogen flocculi evidently indicates that this gas in the flocculi for some reason radiates less light than the hydrogen gas which, probably after diffusing from the flocculi, has spread in a nearly uniform mass over the entire surface of the sun. For the present the simplest hypothesis is to assume that the diminished brightness of the flocculi is due to a lower temperature at these points, perhaps caused by the rapid expansion of the gas as it rises from the interior of the sun into the region of greatly reduced pressure above the chromosphere. On such an assumption it would seem probable that the hydrogen flocculi really represent the hydrogen prominences, which lie at a considerable height above the chromosphere, in a region of very low pressure, where the effect of expansion should have produced the greatest fall in temperature. It may ultimately appear that some other explanation must be adopted, especially since the hydrogen in the upper part of the chromosphere seems to be represented by the smaller hydrogen flocculi which form a network over the entire surface of the sun. It already seems probable, in spite of

the comparatively small width of the hydrogen lines, that it will become possible to secure photographs corresponding to different elevations,

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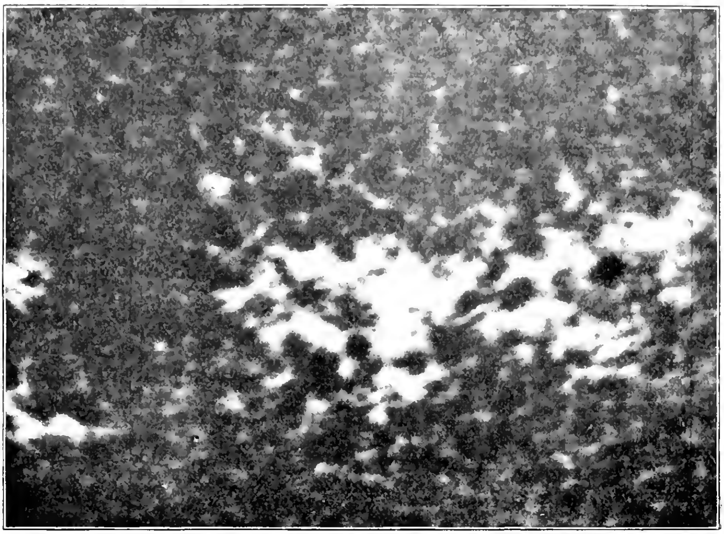

E Fig. 10.—3h 57m. Calcium Flocculi, K_2 Level. Slit at λ 3933.8. *W*

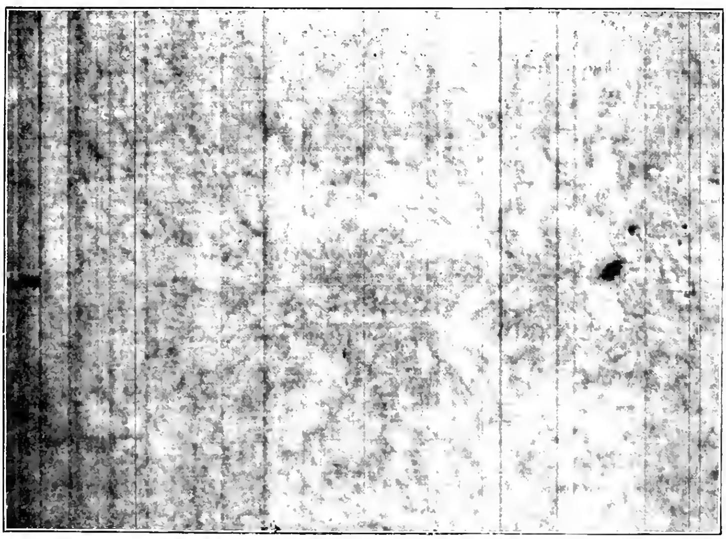

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Fig. 11.—11h 0m. Hydrogen Flocculi. Slit at Center of $H\gamma$. (Bright Eruptive Flocculi West of Spot.)

Hydrogen and Calcium Flocculi, 1903, July 7.

(Scale: Sun's Diameter = 0.290 Meter.)

just as has been done for calcium with the broad *H* and *K* bands. This would permit the lower regions to be differentiated from the

higher ones, and thus assist toward an understanding of the true cause of the apparent darkness. A satisfactory comparison of the forms of the hydrogen flocculi with those of the calcium flocculi can only be made after the question of level has been solved. Although there is a general resemblance in form, as may be seen by reference to Figs. 10 and 11, the differences are nevertheless striking enough to suggest that various researches, interesting on physical and chemical grounds, should be undertaken in the future. For instance, a series of simultaneous photographs, in both hydrogen and calcium lines, taken at brief intervals during the course of a violent eruption, might show interesting peculiarities in the relative forms of the hydrogen and calcium flocculi, corresponding to different velocities and distribution of the respective gases.

The Rumford spectroheliograph has also been used to secure photographs with some of the stronger dark lines of iron and other substances, which show the vapors of these metals on the sun. But even with the grating, the dispersion is insufficient to give thoroughly trustworthy results, except in a very few cases. It is evident that much greater dispersion must be employed if the full capacity of the method is to be brought out in future work.

It is perhaps worth while to consider what are the logical steps to be taken in the future development of the spectroheliograph. As at present used, it is capable of solving a large number of problems if employed systematically to register the changing forms of the calcium and hydrogen flocculi. The method of photographing sections at different levels, and the method of detecting local differences of temperature or of physical or chemical state, should also permit important knowledge to be gained. But to stop at the point reached, when there is so much of promise in the further perfection of the method, would commend itself to no one interested in the advancement of research. The principal requirements of an instrumental nature are:

1. Greatly increased dispersion in the spectroheliograph, through the use of prisms or gratings in conjunction with collimator and camera lenses of considerable focal length.

2. A focal image of the sun at least twenty inches in diameter, of which zones at least four inches wide can be photographed in monochromatic light.

These considerations would point to the use of spectroheliographs, of from 12 to 40 feet focal length, provided with large gratings or with three or four prisms. Such instruments would necessarily be mounted in fixed positions on massive piers. A solar image 20 inches in diameter would involve the use of a telescope about 180 feet long, and the importance of providing for simultaneous photography in several lines at different parts of the spectrum, would require that

the sun's image be formed by mirrors instead of lenses. Thus the telescope should be a horizontal reflector of the cœlostat type. The aperture of the mirrors should be as great as possible, since the high dispersion of the spectroheliograph, even in the most favorable cases, will involve long exposures.

But the most important requisite is such a condition of the atmosphere as will give the finest possible definition of the solar image. This would involve the establishment of the instruments at some particularly favorable site, where careful telescopic tests have shown the definition of the solar image to be exceptionally fine. Such a site is most likely be found in regions where the sky remains cloudless for weeks at a time: a point of great importance, since at such a place the various phases of changing phenomena could be followed up day after day with the same instruments. A still more thorough study of constantly varying solar phenomena could be secured through the cooperation of a chain of suitably equipped observatories, so distributed in longitude as to permit the sun to be kept continuously under observation.

With such large spectroheliographs, employed with a well-defined solar image of sufficient size, it should be possible to study not only the vapors lying around and above sun-spots, but those which constitute the spot itself. With sufficiently high dispersion, for example, it ought to be possible to secure photographs with the slit set at different points on some of the broadest of the 'widened' lines, giving sections of the vapors of the dark umbra of the spot at different depths below the surface. A comparative study of the forms of the umbra, as recorded in different widened lines, and of those bright forms which must appear on photographs taken with Fraunhofer lines that are weakened in intensity or transformed into bright lines in sun-spots, should provide data for the solution of important questions relative to the solar constitution.

But the spectroheliograph, though promising to supply an exceedingly powerful method of attack, is only one of many instruments required in a comprehensive investigation of solar phenomena. Powerful spectroscopes, equaling or surpassing in resolving power the largest instruments now employed in the physical laboratory, must be used simultaneously with the spectroheliograph in a study of the various vapors. In such a research the displacements of lines in various regions, corresponding to the effect of pressure or to the motion of the gases in the line of sight, would play a prominent part. This most precise quantitative work must be accompanied by a systematic record, extending through many sun-spot periods, of the lines which are widened in sun-spots. Furthermore, there should be accurate measurements, with the bolometer or radiometer, of the heat radiated from

different parts of sun-spots and from other regions of the sun's surface. Visual studies of the solar details under the best atmospheric conditions, and direct photographs made in the ordinary way, will also be essential. From such a mass of observations, if systematically made and studied, a considerable increase in our knowledge of the solar constitution might reasonably be expected to follow.

It would be beyond the province of my immediate subject to discuss the methods by which the study of the physical constitution of the nebulæ and stars may be expected to throw light on the past and future of the sun. But I can not refrain from remarking that through recent improvements in reflecting telescopes, and through the further improvements which are promised in the immediate future, a great advance in this department of astrophysical research may confidently be expected. It thus appears that if the powerful instruments required for these investigations can be provided, the opportunity should exist during the next quarter of a century to make important additions to our knowledge of the origin and development of the sun, and at the same time to throw new light on the great problem of stellar evolution.

THE COLLEGE OF THE WEST.*

BY PRESIDENT DAVID STARR JORDAN,
LELAND STANFORD JUNIOR UNIVERSITY.

TO each century is granted one great discovery, and from this its highest thought and action takes its bent. In each century this discovery is never a new one. It has had its prophets and martyrs ages before—men whose lives have seemed thrown away until at last the world moves on and the caravan reaches their point of vision. The great discovery of the eighteenth century was that of the humanity of man. In action this became the spirit of democracy. The great discovery of the nineteenth century was the reality of external things. Carried out into action this means the progress of science. It is the movement of science which makes possible the varied activities of the new twentieth century.

We are gathered together this morning of the twentieth century to dedicate a new hall of science, a new temple to the worship of the truth of nature. It is erected that it may help men to know and to know what they know—to separate their knowledge of realities from their feelings, their hopes, their dreams, their traditions. All these may be beautiful, helpful, inspiring—but truth is something more than subjective satisfaction. To that part of the divine outside of ourselves which we are able to grasp we give the name of science.

In what I may try to say this morning, I shall speak freely in praise of science, of science study and science teaching. It is for this that we are gathered together. When we erect the hall of the poets, then our discourse may be on Euripides and Shakespeare, on Schiller and Browning, and some gentler tongue shall speak the fitting word. Each power of man shall be exalted in due season and no one at the expense of another. It is true that science is a late comer into the educational household, and that finding none too much room at the best, she sometimes unwittingly ventures to claim it all. But that is only for the moment. Knowledge of man and knowledge of the universe do not exclude each other. In urging the claims of science we would not deny one word ever said for training in the humanities or in any branch of these. This only would we claim. There exist forms of culture other than those which rest on the classical tripos. Other men with other powers have an equal right to training. There is no aristocracy in the human mind. Moreover, prescribed courses of study, whether classical

* Address at the dedication of Palmer Hall, Colorado College.

or scientific, or whatever else there may be, must give way to the needs of individual training. Ready-made clothing, even though it take the form of heroic uniform, does not guarantee a fit. The needs of modern life demand actual fitting. The best training is that best adjusted to our own individual needs.

I am told that Colorado College is one of those which aspires to be 'only a college,' a thoroughly good college of course, but that she has no thought of becoming a university. I do not learn this from my friend, Dr. Slocum, and I know that his ambition is boundless. But whether it be true or not, I am going to oppose the idea. She will be a university before you know it. This Palmer Hall may be offered in evidence that the college period is past. Colorado College has already become a university. A university in embryo, perhaps, if you like, but still with all the marks by which the university is known—as certain to become a university in fact, as a pine seedling on your royal hills is sure some day to become a pine tree.

A university in America is a place where men find their life-work, where men think lofty thoughts, where men test for themselves that which seems to be true, where men go up to the edge of things and look outward into the great unknown.

The university does not consist of colleges and departments, deans and dignitaries, rules and regulations. It is not a cluster of professional schools, nor even a group of graduate students. Its spirit is not measured by printed theses, by elaborate examinations, by the number of the hoods of black and gold its doctors are privileged to wear. It is measured by the animating spirit, the spirit of intellectual enterprise, of academic devotion. This spirit will in time create for itself the brick and stone, test-tubes and microscope, book and manuscripts, all the machinery with which a university must work.

In the development of an animal there is a subtle influence, which we can not measure, always at work, and working to the end that the embryo becomes at last that which from the first it was fated to become. We call this the influence of heredity, but to name it leaves more to be explained than there was before. In like fashion, the spirit of the university, the spirit of zeal and devotion, of beauty-loving and truth-fearing which is in Colorado College to-day will make the university an accomplished fact. Truth-fearing—there is no better phrase —truth-fearing is the spirit of the university.

There is no real difference between the American college and the university, and there will never be any. The lower achievement leads to the higher ambition. Many colleges are little, or weak, or lean or narrow universities; yet even the poorest of them may be hallowed by some one's devotion, ennobled by some one's scholarship. It is scholarship and devotion which, in the long run, make the university. Cer-

tain genuine attributes of the true university we may see clearly in Colorado College. For one thing, she is broad-minded. The hall we dedicate to-day stands as one evidence of this, her fair library is another, and still more cogent the wide sympathies and helpful achievements of her professors. I believe most firmly in the educative value of unlikeness in aim and thought. A man may be highly specialized, he must be if he would succeed as an investigator; but a university should be an all-around organism. The school of applied science, the school of literary expression, should not stand apart from each other. The engineering student is likely to become illiterate if he herds only with his kind. He learns many lessons from the finer side of life, from the student of Chaucer or Homer. The literary student tends to become a dreamer or a prig if he is in touch with literary matters only. From the fierce earnestness of the young engineer, whose whole career depends on the soundness of his individual work, the student of the humanities gains most valuable lessons.

For the same reason I believe in the coeducation of men and women. They need not study the same things, though for the most part as beauty is beauty and truth is truth, so mental accuracy knows no distinction of sex. But the influence of wise and cultivated women works for manliness and refinement. The influence of hopeful and strenuous men gives women's work a seriousness and sanity which is a fair exchange for the other. Where coeducation is honestly and rationally tried, it is no experiment at all. In the natural order of things, and in the long run, the American university and every other real university will be a school for men and women, opening its doors to all who can use its advantages or who can share its ideals.

Wherever there is a real scholar—independent, self-reliant, truth-loving scholar—there we have a university. He gives the university uplift, the university inspiration, the university ideal. If he has but one student, that one is a university student. I do not know how many such there be in the faculty of Colorado College, but there are some I know; some peaks which catch the morning sun, and in the presence of these we have the essential element of the university.

In the American scheme of education, the college course is a period of intellectual broadening. It makes men, while the university makes scholars. The German university system admits of no college course. The college is not the American gymnasium. The rigid drill of the gymnasium, intense and narrow, gives way at once to the university when any subject can be pursued in any fashion or no fashion at all. The gymnasium has cast iron walls. She takes no account of individual differences; she will drill but not create. The university is wide open, everything is at the student's hand: science, letters, art, lust or beer. The student chooses for himself, and the university, as an organism, is indifferent as to his choice.

The American university cares for its students, unwisely sometimes in nagging or futile fashion, but still on the whole to their great advantage. She is always a cherishing mother, and as such her children love her. I have never heard a German university called *Alma Mater.* 'Liebes närrisches Nest,' 'dear silly nest.' This Goethe once called Jena, but Jena was held in remembrance not for her loving care, but for the fond follies she, uncaring, allowed her sons to perpetrate. The German university makes no effort to see that her students work wisely, or indeed that they work at all. They are weaned once they leave the gymnasium. There are too many of them anyhow. Most of them go to swell the 'intellectual proletariat' which, so the Germans tell us, with the military proletariat, is a national menace, and so what does it matter?

Bismarck is reported to have said that one third of the German students drink themselves to death, one third die of overwork and the rest rule Europe. In America, the college has tried to change these proportions, college professors have thrown their personal influence to induce young men to lead sane and profitable lives, to keep them from throwing away their future till the time comes to rule. In this work the faculty of Colorado College has long taken an honorable part. It has shown the value of personality; men are saved by fellowship as often as by precept or practise. By personality is built up the college atmosphere, the 'fellow feeling among free spirits,' an agency in higher education as subtle as it is effective. For this reason the value of the college depends largely on the nearness of the professors and students—'They know each one of us by name.' This has been declared as the secret of the education of old Japan. Not professors, not masters, not martinets of high or low degree, but men who were fellow students have been the most successful teachers. The value of a teacher decreases with the increase in the square of the distance from the student. In this matter the smaller universities have a great advantage over the larger ones if they will only be as careful in the choice of teachers. Only those who are near him know that a teacher is great. There are many graduates of our strongest institutions who never in their whole four years came in contact with a professor. Not long since, the editor of an eastern magazine, an able student and a man of strong character, told me that in his college course he had a speaking acquaintance with but one professor. There were a hundred in the faculty, many of them men of high distinction, but what was that to him? His work was laid out for him in a prescribed course, long before he was born, and from young instructors he received all his guidance.

In this lies one value of the study of science. It has but one method, that of the laboratory, that of first-hand contact with the

things as they are. The teacher himself is a part of that contact. He has set the problems, arranged the experiments. The teacher of science does not speak *ex cathedrâ*. He must come down from his chair. He must be among the things of which he speaks and to the student he must be part of them and the student knows him as he knows them—from personal contact. The strength of the colleges of England has lain not in the narrow courses of study, not in the exclusive pursuit of Latin, Greek and mathematics, but in the spirit of good fellowship which these institutions have fostered. The life of the student is a man to man life. The element of personality has been used to the utmost and with results which need not be disparaged even by those most impressed with the narrowness of the training these colleges offer.

The aim of Oxford and Cambridge has been personal culture. The classical tripos of Greek, Latin and mathematics has been only a means to this end. Any other studies, Anglo-Saxon, botany and medieval history, let us say, would do as well if equally removed from the current of human activity and brought as close to living personality. Mere training of the mind was no essential part of the process. To withdraw for a space in the presence of good men and gracious thoughts is an ideal cherished in English culture. 'Sometimes to bask and ripen,' Lowell tells us, 'is, methinks, the students' wiser business.' For the maturing scholar this may be true, but as a practical matter it is surely a universal experience that to the college student 'to bask and ripen' means a period of plain idleness, and idleness soon turns to dissipation and vice. It is better for the student that demands on him be somewhat strenuous. His life is made more effective if he has once learned the value of time and the necessity of doing things when they should be done. A man who has not learned the worth of time before he is twenty-one, seldom accomplishes much afterward. As the university ideal of England is one of personal culture, that of Germany is one of personal knowledge. In the one case, thoroughness is the essential; in the other, personality. An educated German may lack culture—of this there are many conspicuous examples, just as in England a cultured gentleman may lack exactness of knowledge on all points. In America a new ideal is arising as a result of the creative needs of our strenuous and complex times. We value education for what can be made of it. Our idea is personal effectiveness. We care less and less for surface culture, less and less for mere erudition. We ask of each man not what he knows, but what can he do with his knowledge. This ideal of education has its dangers. It may lead us to sacrifice permanent values for temporary success. It may tend to tolerate boorishness and shallowness, if they present the appearance of temporary achievement. Eternal vigilance is the price of scholarship as well as of liberty and other good things.

But the fact remains, the value of science lies in its relation to human conduct. The value of knowledge lies in the use we can make of it. As each thought of the mind tends to work itself out in action, so does each accession of human knowledge find its end in fitting men to live saner and stronger lives. We may, therefore, rest content with the ideal of effectiveness. The American scholar is master of the situation. He can make things go, because he understands them and because he understands himself. He does not shrink from that which appals the men of culture. He is adequate for that which bewilders the erudite. Judged by our best products, there is no finer man on earth than the college man of America, and in proportion, in the future, he will be wiser and more forceful than he is to-day.

In mechanics we know that the force of a moving body is not measured by its substance. Its momentum or effective power is found in its weight multiplied by its speed. This illustration has been used in praise of American science. The power of science lies not in individual erudition. It lies in its striking power. American science is dynamic, it is always under way. In every branch of science, the best American workers have been those most strenuous in their personal efforts, most eager to make their work useful to the world at large. In almost every branch of utilitarian science, America already stands in the lead. This fact England has already recognized with dignified dismay. We hear much of it now, we shall hear more of it still later, for quite as remarkable as the growth of American science is the advance of American schools. Whenever I visit a department of applied science in America, I see that it has doubled its power, its staff and its equipments since the time of my last visit. My visits are not very frequent, perhaps once in five or ten years, let us say, but what will be the end of it? To double once in fifty years is a rare thing in the universities of the old world, but even that in a few centuries would accomplish wonders.

It is one of the laws of mathematics that a geometric progression will long outrun an arithmetical progression, whatever increases by doubling will far exceed the bulk of addition. American science and scientific schools increase by doubling, and will continue to do so. Hence we measure them not by their actual achievements, but by the certainty of a greater future, far beyond the dreams of those who, like ourselves, must be numbered always with the pioneers. To lay the foundation of science, the foundation of knowledge, the foundation of the future commonwealth of Colorado, is the work of the pioneer. Ours then is a glorious part, for the pioneer is a noble function indeed, but the actuality for the future will surpass the brightest dreams of to-day. Let us glance at some of the varied thoughts this enterprise suggests.

A hundred miles away at the foot of the same mountain range lies

your sister university, the official child of the state. It is for you and for her to work in unison, the same in final purpose, somewhat different in the way of reaching it. The most wonderful thing in educational development since Alfred founded Oxford and Charlemagne Paris, has been the rise of the state universities of America. These are schools established by the people, paid for by the people, built for their own good, limited by no tradition, but rising in power and usefulness with the rise of the common man's intelligence and wealth. Great men have built them but these were not kings, nor millionaires, nor politicians, nor priests. They were simply school teachers, with the common man behind them. The material support of the University of Colorado is the personal interest of the many. The support of Colorado College is the intensive interest of the few. The word *intensive* suggests the nature of her opportunities. The state university must concern itself largely with the development of the professions as a whole, the general intellectual welfare of the state. Every citizen has a stake in it, each citizen has the right to make a demand.

The independent college can make its own clientage; Colorado College is not confined to Colorado. It may be cosmopolitan. Its mission is not to raise the level of professional work or of intellectual life in Colorado. It can aim at higher results, though they be less broad, to give the exceptional man or woman an exceptional opportunity, through the use of the finest agencies within a narrower field. Along this lies the future of the privately endowed colleges and universities. We may not do all things worth doing, but we can do some things better than the state universities can, by virtue of an independent position. The superiority of the independent college must be real so far as it goes. It may lie in research, in excellence of teaching or in the loftiness of personal influence; its range may not be so broad, but it may rise higher, it may come nearer to the heart.

I could not be a son of my own fair state, a 'native son' by adoption, did I not say a word as to the glorious climate which Colorado College may add to the roll of her advantages. Here in Colorado, as in California, nature is kind to man, the weather never makes him its slave, never shuts him up to stew in over-heated prisons.

Colorado, like California, is a virile state, one of 'earth's male lands,' to adopt Browning's classification. It has, like California, the three splendid attributes of healthful air, magnificent scenery and physical and mental standing room. It breeds independent, all-around men. Colorado flows red blood. She has the out-of-doors atmosphere —freed from the narrow cramped public opinion that is made in overheated houses, the public opinion of the village of white houses and green blinds, where everybody knows everybody's business. It has the public opinion of the man who stands on his own feet, cares for his

own needs, is sufficient unto himself and has the large charity which sound nerves ensure. The way of Colorado is the warrior's way—'the Bushido,' as they said in old Japan, the way of the rough rider, the way of the quick arm and the tender heart, the way of him who cares only for what men are and not at all for what men say.

Weak men who have been kept good in the east through the upbraiding of maiden aunts often fail in Colorado. Good men grow better there, for they must fight for and justify their virtue. After all that is the only kind of righteousness that counts, vast, burly, aggressive righteousness to which sin is folly; selfishness and vice are things to be avoided as contemptible, as well as shunned as wicked. The scholar in Colorado shares the largeness of his field. The dim-eyed monk, the stoop-shouldered grammarian, these are not his ideals. The scholar is the leader of enterprise, the builder of states.

The air of Colorado is charged with oxygen. It is good atmosphere in which to bring up a boy. In Colorado he becomes an out-of-door man. He expands his chest, he can do things, he becomes fearless because he is adequate. Here in the west we send our graduate students to the east, because we know that it will be well for them to know what homes their fathers came from. They need New England acquaintanceship, English culture and German methods of thought. Far more does the eastern graduate need what the west can give. The life in the foothills makes a man, if need be, of the Harvard doctor of philosophy. The world beyond the Missouri spreads his horizon and the swift oxygen in the Colorado sunshine swells the size of his heart. Some day men will go to Colorado and California for inspiration of force as poets go to Greece for the inspiration of beauty.

The new America is born where things are broad and free, and her finest inspiration where things are grand and strengthening. When the days of the emigrant are over and our people reach their equilibrium, the home of the highest education must be in the west. Whoever has known Colorado, whoever knows the great west will, all his life long, always hear it calling, and wherever he goes he will carry with him a fuller heart and a freer hand for his life in the plains or the foothills, for his life in the regions where the very heavens are cosmopolitan.

I might say a word on the field of local scientific study which Colorado offers. The problems of the local geology have been discussed by my colleague President Van Hise. A region as vast as the Mississippi valley has been crumpled and folded in the stress of the earth to make Colorado. Noble scenery is the raw material of geology. A mighty cliff is an uncovered record of primeval history. In all this history, from the earliest to the latest, Colorado has something to say. The graves of our earliest ancestors, it may be, lie in the hills of

Cañon City. In these rocks at least are found the earliest traces, the earliest by a million years perhaps, of any backboned animals. From these it is a far cry indeed to the shales of Florissant, where in their day the earliest birds went out to catch the latest worm there was, and again to the Green River shales of the northwest with their extinct creatures not very different from their descendants of to-day. When we speak the magic names of Uncompahgre, Ouray, Telluride, Las Animas, Sierra Blanca, Pike's Peak, Long's Peak, Gunnison, Manitou, Saguache—I know them all and know them well—we raise a thousand memories of grand scenery, rich mines, geological problems, the crumpling of continents, the wash of great rivers.

The botany of Colorado runs rampant over all the hills, columbines and gentians, primroses and poppies; sunflowers and lilies; mountain and plain; Colorado is a land of flowers, and better than this, it is a land of problems. Where did they come from? How did they get here? How did they, why did they change? What relation had the movements of the flowers to the vanished glaciers which have left their imprint in lake and moraine, in erratic and sheep-back and furrowed rock, over so much of the surface of Colorado?

In zoology there is equal richness of forms and equal wealth of problem. How came the trout to move from river to river, changing its spots with every change of stream? How did it pass from the Missouri to the South Platte without reaching the North Platte? How from the Platte to the Arkansas with scarcely a change of any kind? How from the Arkansas to the Rio Grande with changes that every angler notices? How again from the Rio Grande to the Colorado? How from the Colorado across the main divide to the Twin Lakes of Leadville? These are problems worthy of a Sherlock Holmes, and the methods ascribed to that mythical personage are the ordinary methods of science. The same process is used, but it is turned to a higher end than the hunting down of human sins and follies. The problems of geographical distribution, their facts and the causes which lie behind them, occupy a steadily increasing place in the world of science and for the study of very many of these problems there is no field so promising as Colorado.

I can not close this address without a word in praise of the honored president of Colorado College. It is the highest duty, the noblest privilege of the president of the college to give the institution its personality. Others may give money and buildings, the state may create machinery by which the college works; it remains for him to make it a living person, an *Alma Mater*, an influence in the formation of character and citizenship. Sixteen years Dr. Slocum has struggled for Colorado College. Sixteen years of courage, devotion, persistence, of a type few other colleges have known. He has sought far and wide

for good men, for men of his kind. He has seen richer institutions draw these men away, and then he has begun his search once more, and each time he has closed the ranks with men of the Colorado spirit. Every great university has been enriched by men drawn from Colorado College. Greater institutions have stood ready to bid for his own services, and in no mean fashion. This I know well, though not from him. But he will not leave the work of his life to begin another, simply because the other stands in a larger yard. There is gold in Colorado, there is silver, there is untold wealth in her mines. But Colorado is not made by mines. She has been made by men. She has had many red letter days. This twenty-third day of February, 1904, is not the least of them all, but none has been fraught with greater hope to the state than that day sixteen years ago, that day when William Frederick Slocum came to the presidency of Colorado College.

The building we dedicate to-day is called Palmer Hall. It is in large degree the gift of General William J. Palmer, and it rightfully bears his name. I never met General Palmer personally until yesterday, but I have long known his name as that of one of Colorado's most enlightened citizens. I trust that he may live long to see his noble gift used and appreciated.

There is no way, I believe, in which accumulated wealth can be so wisely used as in the endowment or enrichment of colleges. In no way can the present secure such pledges of the future, and no gifts are so unselfish as those made to posterity. All who help to promote scholarship, citizenship, efficiency, are patriots in the highest sense and their patriotism should be appreciated by the people.

In all the range of mean-spirited criticism there is nothing more contemptible than that which ascribes selfish aims to wealthy men who give to colleges. Sensational neurotics are constantly in fear that the rich man will force the college to teach his doctrines. Such a thing has never happened, for it requires brains to acquire wealth and this implies sense enough to understand the freedom of the university. No rich benefactor of our day has ever tried to use a university as a tool; no one ever will try. Yet the clamor having this as a burden goes up from one end of the country to the other. Over the shoulders of the college the blackmailer tries to stab at the millionaire. But he goes on his way unmindful, and if he be generous-minded, he makes his gifts just the same, sure of the results of the future, even though denied the gratitude of the present.

Here in Colorado there rules a saner spirit. Our Palmer Hall is the gift of a kind and helpful friend. As such it is received by all who are here to-day and by all true and loyal citizens of Colorado.

Finally let me say: In all plans of university building there is but one that succeeds. Those who think for themselves will inspire

others to do the same. Where teachers are original investigators truth-fearing and truth-loyal men, men that can not be fatigued or discouraged, their students will be of their own kind. To find them, they will come from the ends of the earth. The investigators make the university as the teachers make the college. It is not necessary that many departments be developed to make the university real; it is said that Agassiz in 1850 was himself the sole university in America. The presence of Agassiz and Gray, Lowell and Longfellow, Holmes and Goodwin, Felton and Norton, meant a university atmosphere. Silliman and Dana meant the University of Yale. Such men are as rare as they are choice. No university faculty was ever made up wholly of university men, and no one ever had too many of them.

From such men as these the American scholar is descended. The growth of American science is his work, and of this growth he is in turn a product. That he may never grow less we hope and pray. And this with a certainty that our prayers will meet their answer. Our faith is shown by our works. With the best of these let us place our new temple dedicated to the holy life of action, to the worship of the God of things as they are, our new Palmer Hall of Colorado College.

A QUESTION OF PREFERENCE IN ENGLISH SPELLING.

By Dr. EDWIN W. BOWEN,

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WE little think when we read or write that the words we employ are not precisely the same as those which have been in use in our mother-tongue from time immemorial. We are born into the language, so to say, and the words of our vocabulary we regard as part and parcel of our rich heritage of American liberty. Yet even the words of our English speech, like many of the institutions and customs of our Anglo-Saxon civilization, have a long history back of them, showing traces here and there of the various stages of development they have passed through. The words we use to-day are not identical in form or meaning with those employed by our forebears of the generation of Chaucer or even of the generation of Shakespeare. The forms of our English words have undergone considerable change since that remote period in the development of our mother-tongue. English spelling is far different from what it was in Alfred's, or Chaucer's time.

Before the invention of printing, those who spoke and wrote the English language seem to have been at liberty to spell as they chose. Their mental composure was not disturbed by the annoying suspicion that their spelling was not according to the norm prescribed by the dictionary. In those good old days there was no acknowledged criterion such as the 'Century,' or 'Webster,' or 'Worcester'; and writers had no final appeal in the matter of orthography as present-day writers have. Since there was no standard authority on orthography to which all polite society had to conform, the authors of the thirteenth and fourteenth centuries were untrammeled by tradition and were free to spell as they pleased. Every writer was a law unto himself and followed the dictates of his own orthographical conscience, with no dictionary to molest or make him afraid. We find an allusion to this delightful sense of freedom in the comment which a well-known American humorist made upon Chaucer, that well of English undefiled from which so many modern writers have drunk copious draughts of inspiration. 'Chaucer,' said he quaintly, 'may have been a fine poet, but he was a —— poor speller.'

The diffusion of the art of printing and the consequent necessity for a uniform orthography gradually curtailed this liberty, and then the day of the dictionary dawned. The dictionary is a democratic

invention called into being by the rise of the great middle class of society, which desired to become familiar with the practises of polite circles. Lexicographers came forward to supply the desired information. Authors not to the manor born, and therefore unacquainted with courtly usage, when moved to write, felt that they must conform to the standards set up by the lexicographers, who claimed to give the received usage, the *jus et norma scribendi.* Before the epoch of dictionaries it appears not to have made the slightest difference whether a writer spelled the word *recede,* for example, according to the present accepted orthography, or whether he spelled it *receed, receede, receade* or *recead,* all of which forms are found in manuscripts of a few centuries ago. Some of these orthographic variations lingered into the eighteenth century, though English spelling had probably become stereotyped at least a century before this date. Yet the establishment of the spelling was naturally a gradual process, and some words vacillated a long time and never really became fixed. Of this more anon. Proper names showed considerable latitude of spelling. Men of the eminence of Spenser, rare Ben Jonson and Shakespeare, for example, are said to have had no fixed practise of spelling their names, but wrote them in a variety of ways.

The lack of a standard authority of orthography necessarily gave rise to much confusion and disorder in English spelling. This confusion is reflected even yet in the present chaotic and unphonetic spelling of our language. Few tongues are more unphonetic than the English. This fact is recognized and efforts have been made to bring our spelling into closer conformity with our pronunciation. Philological societies on both sides of the Atlantic have been trying for the last quarter of a century, at least, to reform English spelling; but only meager success has been achieved thus far.

The proposed reforms have been of two kinds, and they have varying aims. One, recommended by the extreme phonetists, is a reform which contemplates a revision and enlargement of our alphabet. This would result in a radical transformation of our written speech, and chiefly for this reason it has found few ardent advocates. It may be briefly described as a reform of the language. The other reform is less revolutionary and contemplates mainly a simplification of our present spelling, such as the omission of silent letters, the substitution of 'f' for 'ph' as in *phonetics* (fonetics) and of 't' for final 'd' as in *equipped* (equipt) and similar emendations. Of the two kinds of reform the latter has, manifestly, more to commend it to popular favor. This kind of reform may be termed a reform in the language.

The public concedes the unphonetic character of English orthography, but the conservatism of the Anglo-Saxon race is so binding that the people are slow to adopt even the slightest recommendations of the philological societies. A few American journals have had the courage

to adopt certain emended spellings, such as *thru* (through), *tho* (though), *catalog* (catalogue) and the like, but the majority of our periodicals show by their practise very meager approval of spelling-reform. No publisher, so far as known to the writer, has ventured as yet to use the emended spelling in a book issued by his firm. Yet all admit the need of spelling-reform and believe that, if adopted, it would save the coming generation a vast deal of humdrum work in acquiring an accurate knowledge of English orthography.

We Americans, however, with our characteristic spirit of independence have made bold to break away from British tradition and custom in the writing of certain English words and have introduced a few minor reforms in our spelling. But the English people have not followed our lead in this matter, being content to allow our adopted American spelling, together with our distiuctive pronunciation, serve as an earmark to distinguish American from British English. It is the practise of some reputable British journals to disparage our spelling, wherever it makes a departure from English traditions, and to refer to it by way of reproach as 'American spelling.' Some few years ago the *St. James Gazette,* intending to express its disapproval of our spelling, deprecatingly remarked that "already newspapers in London are habitually using the ugliest forms of American spelling and those silly eccentricities do not make the slightest difference in their circulation." Viewed in the light of subsequent events, perhaps this ought to be considered as the forerunner of 'the American invasion.'

As every one knows who has visited the mother country, there is a perceptible difference not only in the spelling, but also in the pronunciation, between American English and British English. Of course the language is the same in America as in England; and yet there are some appreciable minor points of difference. For example, the Englishman gives the broad sound to the vowel *a* as in *father,* when it is followed by such a combination of consonants as in the words *ask, fast, dance, can't, answer, after* and the like. In America, on the other hand, while this pronunciation is heard in some circles, it is clearly not the ordinary pronunciation and is not general, as in England. There is also a noticeable difference in the pronunciation of long *o,* the Englishman giving the vowel a distinctive utterance quite unlike that ordinarily heard in America. The pronunciation of the word *been* is a shibboleth by which a man of British nationality may be almost unfailingly distinguished. The native Englishman pronounces the word so as to rhyme with *seen,* never *bin.* In addition to these points of pronunciation there are certain locutions which never fail to betray an Englishman. The English call an elevator *a lift,* overshoes *galoshes,* napkins *serviettes,* candy *sweets.* In England a baby-carriage is called a *perambulator,* which is generally abridged '*pram*' merely; a lamp-post is known as *lamp-pillar* and a letter-box

as a *pillar-box.* There no one would ask at a store for a wash-bowl and pitcher, however much he might need these useful household articles, but he would call at the shop for a *jug* and *basin.* An American in London must not say street car, but *tram* or *road car;* not engine (which is pronounced injin), but *locomotive-engine;* not engineer, but *engine-driver.* In England many ordinary household articles are known by names as different from those in our country as if the language there were altogether a foreign tongue. Small wonder, then, that a keen-witted American maid remarked, *à propos* of the difference between British English and American English, that London was a delightful place if you only knew the language.

Nowhere is the difference between American English and British English more marked and interesting than in the varying practise of spelling on both sides of the Atlantic. Let us note some of the chief points of variation.

Our British cousins assume an exasperating air of superiority when they mention the matter of our spelling and, as self-appointed conservators of the language, point out what they are pleased to style the offensive eccentricities of American spelling. The British journals ever and anon draw attention to our manner of writing such words as *favor, honor, center, program, almanac, tire, curb, check* and *criticize* and the like, which they spell *favour, honour, centre, programme, almanack, tyre, kerb, cheque* and *criticise.* Now, in the case of most of these words, we submit that the American spelling is nearer the historical spelling, simpler and more logical than the British method. As for the words typified by *honor,* our method is simpler and nearer to the ultimate etymology. These words, it hardly need be observed, are borrowed from the Latin through the French. The British maintain that for this reason the spelling ought to conform to the French fashion. But they overlook the fact that these words have not always been written in English according to the French manner of writing. Dr. Johnson, the eminent lexicographer of the eighteenth century, wrote *honor* beside *honour, neighbor* beside *neighbour, harbor* beside *harbour* and the like. Indeed, the great Cham allowed himself considerable latitude in the matter of English orthography. Moreover, the Norman-French forms of these words were written in a variety of ways, as *our, eur, ur,* and also *or.* Even on the historical ground, therefore, there is not lacking some authority for the American spelling. If the English were consistent, they would be forced by the logic of their argument to write uniformly *govenour, errour, emperour, oratour, horrour* and *odolour* as well as *honour* and *favour.* But practise shows their glaring lack of consistency, since they do not spell these words ordinarily with *u.* It ought not to be regarded as a reproach upon American spelling, because in our desire for simplicity and uniformity we have rejected the *u* in this entire class of words

like *honor,* thus making the spelling more in keeping with the Latin derivation. We can at least lay claim to simplicity and consistency. If we are provincial, we can not be charged with arbitrariness in our spelling.

As for the writing of *center, meter, meager* and words of this kind, the American method has as much history and logic in its favor as the British spelling has. Analogy, too, if that may be cited as an argument, supports our spelling, for we all write *perimeter, diameter,* never otherwise, whether we be American or English. The word *center,* according to Lowell, who was no mean authority on matters pertaining to our speech, 'is no Americanism; it entered the language in that shape and kept it at least as late as Defoe.' "In the sixteenth and in the first half of the seventeenth century," declares Professor Lounsbury, in reference to the spelling of *center* and similar words, "while both ways of writing these words existed side by side, the termination *er* is far more common than *re.* The first complete edition of Shakespeare's plays was published in 1624. In that work *sepulcher* occurs thirteen times; it is spelled eleven times with *er. Scepter* occurs thirty-seven times; it is not once spelled with *re,* but always with *er. Center* occurs twelve times, and in nine instances out of the twelve it ends in *er.*" John Bellows, in the preface to his excellent French-English and English-French pocket dictionary, states that "the Act of Parliament legalizing the use of the metric system in this country [England] gives the words meter, liter, gram, etc., spelt on the American plan." It is evident, then, that our way of writing these words is quite as logical and as much warranted by the history of our tongue as the British spelling.

The American orthography is clearly in advance of the British in the word *almanac.* This word is not rightly entitled to the final *k,* as the English spell it. This superfluous letter is a mere survival from a former way of writing, no longer in vogue. It has been rejected in *music, public, optic* and similar words which are written alike on both sides of the Atlantic. In Johnson's dictionary and also in our King James's version of the Scriptures the old spelling generally occurs. Indeed, Johnson appended the excrescent *k* to well-nigh all words of this class. Strange to say, there is one word of this class which preserves the *k* even in American English, and that is *hammock.* This is but an exception which goes to prove that even American English with its revised orthography is still far from being phonetic.

In regard to words ending in *ize,* usage in Great Britain has established the writing *ise,* as in *civilise.* However, new formations even there are usually made to terminate in *ize,* which is generally adopted in America. Yet American spelling sometimes exhibits *ise,* after the English fashion. The British writing is derived from the French, whereas the American harks back to the original Greek suffix. The

British spelling of *tyre, kerb, programme* and *cheque* perhaps has as much to commend it as the American *tire, curb, program* and *check*. Usage in America varies in the case of *program,* the more conservative still clinging to *programme*. *Tyre* and *kerb* are but little employed here. These words are merely variant forms which British usage has adopted. The spelling *cheque,* in general use in Great Britain for our bank check, has resulted through the influence of the word *exchequer* with which it is connected.

The usual American spelling of *wagon* is held up to public obloquy by British journalists, who regard *waggon* as the orthodox orthography. Skeat, who gives both forms in his etymological dictionary, asserts that the doubling of the *g* is simply a device to show that the preceding vowel is short. In the early history of the language when the etymological spelling was in vogue, pedants had recourse to this method of changing the form of a word to make it phonetic, as they claimed. In point of fact, by their practise they made the language far less phonetic. Spenser and other early English authors write the word after the American fashion. Horace Greeley once made a departure from our American usage and wrote *waggon,* saying by way of apology, when his attention was called to it, that 'they used to build wagons heavier in the good old times when he learned to spell.'

It is not to be supposed for a moment, however, that our utilitarian disregard of tradition is so strong as to have eliminated all useless letters in our American spelling. There is many a word in which an epenthetic letter is still retained merely because the traditional spelling shows it. *Sovereign, comptroller, island* and *rhyme* may be cited as examples in point. Perhaps it ought to be added that the emended spelling *rime* for *rhyme* appears to be meeting with favor in certain philological circles.

There is one class of words which does not exhibit a uniform method of writing, either in Great Britain or in America. This class is typified by the words *traveler, counselor, worshiper* and the like. It will be readily seen that these words are all derivatives, formed from the primary by the addition of a suffix; and the writing vacillates between a single and a double consonant preceding the suffix. According to the well-known principle of English orthography, these words are not entitled to a double consonant, and therefore should never be written *traveller, counsellor* and *worshipper*. The rule is, if the final syllable of a word ending in a single consonant and preceded by a short vowel is accented, the final consonant, on the addition of a suffix beginning with a vowel, is doubled; but never otherwise. Thus we write *offered, deviled* and the like, but *referred, transferred* and *jammed*. Hence the orthodox spelling should be *traveler, counselor, worshiper, unrivaled* and the like. But practise shows that either spelling is regarded as correct on both sides of the Atlantic. These

words are survivals from a former period in the history of the language when more latitude was allowed in English orthography and there was no hard and fast line drawn, no fixed standard. The proper historical spelling, it is interesting to note, is with one consonant, as in *counselor* derived ultimately from the Latin *consiliarius*. While either spelling is considered correct, British usage favors the double consonant (*counsellor*) and American the single (*counselor*). Here again as elsewhere American spelling inclines to simplification and would make these words conform to the general rule of English orthography as laid down above. Strange to say, British usage shows one exception in the word *paralleled,* which it has adopted (and not *parallelled*). Here we find another instance of the striking inconsistency of British orthography. It may be a shocking thing to say, but investigation will prove it true, that if those British critics who censure our spelling so severely, as offending their esthetic sense, were more familiar with the history of the language, they would, without doubt, have far less comment to make upon the so-called eccentricities of American spelling.

It remains to notice some apparent exceptions to the rule of English orthography stated above. Noteworthy among these are the words *handicapped* and *kidnapped,* which are written alike in British and American English. But they can be explained and are only apparent exceptions. A moment's reflection is sufficient to convince one that *handicap* and *kidnap* are not simple words, but in reality compounds in which the last element has not completely lost its identity in combination. Because of the consciousness of the independent words *cap* and *nap* in these compounds, they conform to the rule as a matter of fact and therefore double the final consonant, on the addition of a suffix beginning with a vowel. Hence, if they are exceptions, they must be considered exceptions which prove the rule.

The few points we have drawn attention to in this imperfect little sketch are enough to show how unphonetic and illogical is our English spelling. Many of the eccentricities of our orthography, according to Skeat, have resulted from the futile attempts of pedants in the sixteenth century to make English spelling etymological and to make it conform to the classics, from which a vast multitude of words had been introduced into our speech. These conscious attempts at etymological spelling gave rise to endless confusion and disorder. But other causes, such as analogy and mere caprice, also contributed to this end. Thus we are to explain the writing of the word *female,* for example. This word, coming from the Latin *femella* through the French *femelle* into English, was originally written *femelle* and would probably have retained this form to the present time. But because of a fancied connection with the word *male*, the spelling was changed to *female*. In a similar manner is to be explained the spelling of numerous other words in our language which seem perfectly natural and logical on first blush.

ALUMNA'S CHILDREN.

BY AN ALUMNA.

THE latest publication of vital statistics in Massachusetts has again called attention to a subject often discussed in this magazine and elsewhere—the decreasing number of children in native American families. According to the majority of opinions given, this decrease is due mostly to 'social ambition.' This means that the women who should be, in a real sense, the pillars of our society prefer other things to bringing up their own children. If this is true, it seems a very serious indictment of the American woman.

But is the case settled yet? While social ambition may be operative in many cases, perhaps peculiarly among those coming to the notice of a specialist in medicine, may there not be some data that the statistician can not collect—some pertinent facts which in the nature of the case are not within reach of the investigators?

Among all the talk by learned men and high officials, it is strange that no member of the class under discussion has spoken to the question. On further thought the reason is obvious; the case is necessarily of great delicacy and incapable of proof. But because the charge seems to me in many cases so peculiarly unjust, hereby do I rush in where angels have feared to tread.

Dr. Engelmann in his especially interesting article spoke particularly of the college graduates, that 'group having a lower birth rate than any other.' There may be no need to separate alumna from the rest of her racial group for consideration, for the body of college women now is made up of nearly all the elements of what may be called the middle class. But because narrowing a subject makes it easier to view; because the birth rate of the alumnæ is the very lowest; and, especially, because I happen to know more of the conditions among college girls, I confine myself to that group.

There is no need to question the figures—that 1.8 children is the average family of an alumna wife; but let us consider in the beginning just what that 1.8 children mean. Incidentally, we may think a moment of the marriage rate among college women. Both these relatively low numbers are inspiring in one respect—in the thought of the elements which have been eliminated. If less than 50 per cent. of college women marry, yet of that number few take husbands 'for a home' or because they have nothing else to do. Perhaps there are as many happy marriages of companionship among a hundred college

women as among a hundred women selected from any class, and does the state lose by the elimination of all others?

Alumna's marriage, then, means that a mature, independent, trained woman deliberately chooses to give the direction of her life to a man, because she loves him well enough to find in so doing her greatest happiness. Of such a mating are alumna's children born—of a 'selected' father, of a mother who has at least had an opportunity for knowledge—born to a heritage of intelligent love and care. So they ought to be a power for good, even though they are few. But just because they are of such a quality, society wants more of them; and it behooves the state to determine why their numbers are so few.

Yesterday I received some evidence on this question which seemed to me pertinent. I spent the day with a member of this group 'having a lower birth rate than any other.' She had recently buried her only child, hardly a month old. As I was on my way to her, my mind went over her past year; her hope that she might at last be strong enough to bear a well child, the months of illness, the forty-eight hours of agony, the supreme joy so soon followed by anxiety, and the awful loss. And when I saw her face I could not speak. But she spoke, and with a smile: 'Don't pity me so. It paid! it pays!' During the hours I spent with her she showed me two books of letters, mostly from college friends of ours. One collection was received when her baby came, the other when he went. 'I am so happy to know that your life has been made complete'—this thought was expressed over and over again in the letters of congratulation. Mothers or childless, all these women seemed to know that any woman's life is incomplete until she has known motherhood. Of those notes that came at the little one's death from childless women, married or single, all said, in one phrase or another, 'how much sadder than yourself am I, who have no child to die.' These letters inevitably suggest the question, why are so few of these women mothers, when all of them speak of motherhood as life's greatest good? It seemed to me a very solemn question, and I went over the list of those whom I know best and found what seems to me a suggestive unanimity.

There is A, the brightest girl in our class, kept from the really brilliant literary career of which she is capable by her physical weakness. She loves a man who is her ideal mate and he returns her love, but they live their lives apart. A short time ago I said something to her about her being married. "Be married!" she said. "What right have I to be married? My physician tells me that I am no more a woman physically than is a twelve-year-old girl. What right have I to give to any man an invalid wife and take away from him his hope of children? I shall never be married!"

B has just adopted a baby, 'because I may never hope to have one

of my own,' as she wrote me. C, apparently well during college days, came to decennial the mother of three children, but such an invalid that she only with difficulty sat up during class dinner. D had one child who died at birth, and no other has ever come to her. E, an especially close friend of mine, has one child and longs for more, but her physician husband is unwilling that she should again take the risk, saying she was 'never meant to bear children.' F's case is almost the same; a woman of magnificent physique, she refused to heed her doctor. Her first baby lived, but she barely escaped herself; her second child was sacrificed to save its mother's life; 'and I can never hope for another,' she said to me, her eyes full of tears. G also would not believe her physician, but her hope was finally justified. Though three times she was disappointed, her fourth suffering gave her a son, who, she says, much more than pays for all. H has two strong, beautiful children. 'I wish we had six,' said her husband, a college dean, by the way, 'but the two that we have cost their mother so much that we shall never have any more.'

These women are all among my classmates, but the conditions are not peculiar to my class or to my college. I could cite as many instances among other college friends, but they are so nearly identical that they would seem merely a repetition. Two friends of mine now are fighting hard for the lives which have been threatened ever since their first babies came, in each case over a year ago. The example of greatest courage, perhaps, is not a college woman, though decidedly a schooled woman. Five times she went to the very gates of death for her great hope, but only once did she see the face of a living child of hers, and he died at six months.

In connection with a woman's ruling passion, I always think of that gracious lady preeminent as scholar and citizen, who recently left this world so much the poorer, especially for those who enjoyed the distinction of her friendship. I once heard a woman ask her whether she had any children. "Do you suppose," she replied, "that if I had any children, I should be running around the country talking?" And her tone said 'since all that my life seemed meant for, fails,' though all other honors were hers, save only motherhood.

Throughout my acquaintance, among not only my college friends but also my husband's college friends, I find, it has seemed to me, a large proportion of childless homes. And wherever a word has been dropped in my hearing as to the feeling of the wife in the matter, it has always been referred to as a great sorrow. I have been considering the question for some years and have tried to receive any light that appeared.

In many homes that I know there is an only child. It may seem that here are mothers who can have children but do not want them.

The only child does not mean this, but that the one came so near costing its mother her life that he to whom she is dearer than even his hope of children can not bear to let her undergo the ordeal again. Dr. Engelmann has referred to the fact that men more often than their wives wish to limit the number of their children. I shall never forget the pathos of the day when K, a boy who had graduated from college and married hardly a year before, came to tell me of the birth of his son. For twenty-four hours his wife had striven between life and death; as soon as she was out of immediate danger, he came to me, her long-time friend, and broke down. 'If this is what babies cost,' he said, 'there will never be any more at our house.' The son born that day is seven years old, but he is still an only child. I know many instances where children are few because the one or two who have come 'have cost their mother too much.'

These women are not cowards. Undoubtedly the first six hundred women who cross the campus to-morrow morning would make a Balaklava charge without a desertion. But how many men would go one by one into an advance in which they have been told there was no hope of winning and every chance of being left burdensome cripples for life? I have known many, many college women who have said, 'I *will* have my baby!' Some of them died for the faith that was in them, some of them are happy mothers; a good many are invalids, of higher or lower degree.

Occasionally we find an alumna who, not strong before maternity, is well thereafter. The stunted system develops, and she becomes the woman that she was meant to be. And what beautiful families these women have! I recall two; in one there are four children under six, in the other, five under twelve, and all hearty, beautifully brought up children.

That it is alumna's misfortune, not her fault, that her children are so few I do not expect to *prove*. The testimony for the defendant can not, in the nature of the case, be brought into court. Even were I made an accredited observer, the examples quoted could give no scientific proof, since so small a per cent. of the class has been examined. But naturally they influence my opinion because they are 100 per cent. of the cases which I happen to know all about. But I can not even say 'name and address given on application,' as the patent medicine advertisements promise.

The theory which attributes childlessness to physical weakness is by no means a new one. It has been consciously or unconsciously suggested over and over again by students of vital statistics. Dr. Holmes touches upon it in a medical address given in 1867; the declining birth rate was attracting attention even then. And again and again in discussions of the subject by students who are advancing

various theories this element in the problem appears. Among later utterances, Dr. Engelmann said, 'Race decline is not due to education, not of the educated man at least. The educated woman is in a different class.' Professor Thorndike concludes that 'the condition is due to a decrease in fertility in the racial group to which college men *and their wives* belong.' In passing we might quote another sentence of his: "The opinion of metropolitan physicians may here be as wide of the mark as the common belief that unwillingness is the cause of the failure of the women of the better class to nurse their own children."

If you grant me for a time that the cause of the 1.8—it seems like the judgment of Solomon to speak of tenths of a child!—be physical inability, what is the cause of this inability among the, let us say, schooled American women, with the rate the lowest among those who have been longest in school? What is the cause of the extirpation of that function which one would think would be of all others promoted by natural selection? Is our system of education an element in this result? These questions are surely vital in more senses than one.

Thus far I have been sure of my ground, even if I could not make it clear. Now the way is more obscure, for undoubtedly different influences operate in different classes to undermine the health of our girls. If this weakness of function appears especially among college girls, is then the college course at fault? The birth rate is only a little lower among the alumnæ, and we may find that their disability is due to conditions not directly a part of the college course, which each college woman undergoes and only nearly all other women. Observation has almost universally brought the report that the average girl improves in health during her college course.

Is then the responsibility in the high school, where the greater part of our girls do their preparatory work? Very many girls break down here, we know. Frequently a high school teacher attributes a high school boy's inaccuracy in arithmetic or his slovenly English to 'poor preparation in the grammar grades.' This may or may not be just, but I wish some one could find how much of the poor health in high school and college and during later life is due to the way in which our girls go to the grammar school.

'The way in which they go.' There is no especial fault in the content of their education, primary, secondary, collegiate or university. There is no need of making their curriculum feminine, lest womanly instincts be dulled. It is the way of taking the schooling, the physical demands of it, that have been responsible for most of the invalids that I have happened to know. Alumna's fate was sealed when she was in the grammar school.

When the bee larvæ are about a week old, you remember, it is determined whether they shall become queens or workers. It is simply

a question of nourishment; the queen has an abundance of the best food; the worker has a limited supply of inferior quality. The result is a stunting of the reproductive system of the worker bee.

May it not be possible that a similar effect comes in some degree to our women from our school system? The grammar school girl is a larva, if you please, at the age when she should develop a new system of her being, vital both to herself and to her race. To perfect these organs she needs all her rich red blood, all her nervous force. If the brain claims her whole vitality, how can there be any proper development? Just as very young children should give all their strength for some years solely to physical growth before the brain is allowed to make any considerable demands, so at this critical period in the life of the woman nothing should obstruct the right of way of this important system. A year at the least should be made especially easy for her, with neither mental nor nervous strain; and throughout the rest of her school days she should have her periodical day of rest, free from any study or overexertion. Most school girls have many unhygienic habits, all of which tend toward checking her development. Exactly these points were suggested in an editorial note in this magazine some months ago, I remember. The physical conditions and irregularities general among high school girls are appalling, in reference both to their own enjoyment and to the larger interests of the race.

But this is not an argument against our system of education in itself; the matter is not one for school boards to regulate. The intelligent fathers and mothers of our little girls of to-day are the only ones who can remedy these conditions. They can make the girl take one easy year, even though it means 'losing a grade,' that bug-a-boo of school girls; and they can keep for her her needed days of rest throughout her course. Even a year's delay in graduation is not so bad as a dwarfing of development. To hear a school girl speak to the question of her waiting a year, one would judge that existence out of her own particular class would necessarily separate her from all the desirable pupils in school. But those arguments—have you ever noticed?—are never employed when a girl is given a double promotion and advanced a class.

Losing a grade would not often be necessary, however. Ideal conditions would permit a mother to take her daughter to herself for that one year—to teach her the school work and all the other things in which she needs wise and loving instruction especially at this time, welding a companionship which will be the greatest possible barrier against future mistake and sorrow for the young woman in shaping her life.

That it is not always possible for a mother to follow this course I recognize, though it might be arranged much more often than it is if

once the mother realized what it would mean. When the mother can not do it, perhaps she can arrange for a little time of private lessons, when her daughter, working at just the rate right for her, can accomplish a term's work with a minimum of study and with none of the nervous strain which comes from competition. I can think of nothing better worth a mother's time than to establish her daughter's health for the rest of her life and make possible for her all the blessed things that womanhood may mean.

Finally, there is no doubt that some husbands and wives limit their families to one or two that they may thus do more for those few children, or have none because they can thus do more for themselves—'social ambition,' in other words. There may be to some extent a decrease in race fertility in certain racial groups without other signs of physical deterioration; yet there seems to me an amount of evidence too large to disregard which goes to show that the small families among schooled women are due to the physical weakness of the wives. Ask yourself how many really strong women you know. And while there are undoubtedly differing conditions operating in different classes and in different countries, and the contrasts between England and Germany (the birth rate is even lower for the English alumna than for the American), France and Italy, the United States and Canada, can by no means all be explained by this theory, yet I wish some investigation could be instituted to determine how much of the decrease of birth rate among native born American women comes from arrested development in our young girls—due in some classes to lack of proper food, to lack of sleep, to physical overwork, but in very many cases to their unwise manner of work and to untimely nervous strain in our grammar and high schools.

ON THE STUDY OF PHYSICS.

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THE domain of physics is coextensive with the whole range of phenomena of the material world, but the science of physics, as commonly understood, is restricted to a much smaller field whose boundaries were perhaps first marked by setting off certain groups of phenomena for special study.

In this way there arose five significant branches of physical science: (1) Astronomy, in which are treated the facts and phenomena observed in connection with the heavenly bodies. One peculiarity of astronomical phenomena is worth noting, namely, that they are entirely beyond human control and can not be made the subject of experiment. (2) Chemistry, which treats the relations of different kinds of matter one to another, and those phenomena which accompany material changes, *i. e.*, alteration in the composition of substances. (3) Biology, which deals with vital phenomena; current, as in physiology, or past, as in paleontology. (4) Meteorology, in which are grouped phenomena peculiar to the earth's atmosphere and incapable of repetition at will. (5) All the remaining natural phenomena form the subject of physics, which may be said to treat of mechanics, *i. e.*, the motion and interaction of bodies upon one another, and of those groups of phenomena commonly designated as heat, light, sound and electricity. These conventional divisions of science involve other differences not always clearly apprehended, but important alike to the student and the teacher.

While one may not say that one branch of knowledge is more worthy than another, one set of facts may be more precise or scientific than another, whatever may be the meaning attached to the word. Exactly where to draw the line between science and knowledge has been the subject of some dispute. For the purpose of the present discussion we will adopt as the definition of a science, the precise knowledge of a body of facts accurately verified and erected into a logical system. In this definition, only those branches of learning are intentionally excluded from the rank of science in which the knowledge is either ill defined, or uncertain, or unsystematized, though just what classes of historical investigation or of psychological speculation fail to meet the requirement are of no moment, as we are at present concerned only with branches of physical science. It is obvious that the branches of science thus defined may differ considerably in the precision with which the facts

may be stated and in the correlation of the parts of the system, varying all the way from mathematics, which is the science of exactness, to certain branches of natural history, which are no more than catalogues of the forms of life arranged in arbitrary classes and termed science only because they are sciences in the making, the first step always being to arrange the facts in order, even though it be an arbitrary one. Because these differences are often forgotten and sometimes ignored with consequent misapprehension and even serious error, they deserve further review and illustration.

Every science starts with a few postulates suggested by universal experience. These assumptions thus become for that particular science the ultimate things, in terms of which all its conclusions are stated, and they are not, at least as far as that science is concerned, capable of further simplification. The simplest illustration may be seen in the case of mathematics, though many of its followers do not recognize that it is a physical science at all.

Number is a common and easily distinguishable property of all bodies and of all phenomena. By the process of grouping and counting we derive the fundamental laws concerning collections of bodies, such as the associative law, the distributive law, the permutative law, etc. Having secured its fundamental data from the physical world, mathematics withdraws, so to speak, into the realm of thought and, aided by reason alone, weaves its material by successive steps into those remarkable systems which we call arithmetic, algebra, the infinitesimal calculus, the theory of functions, etc. In a sense mathematics is the most fundamental of the sciences, for without it comparisons would lose that element of exactness which alone endows them with the rank of science.

Geometry, though often reckoned as a branch of pure mathematics, is more definitely a physical science than the science of number, since it deals with extension in space, a phenomenon entirely within the domain of physics. But geometry having derived its postulates, or axioms, as they are commonly called in this connection, from experience, like the science of mathematics retires with these data into a world of abstractions; a world deprived of all realities save spatial relations and the laws of thought, and here develops a system self-contained, *i. e.*, requiring no further appeal to the physical world or to human experience.

A procedure similar to this is indeed frequently employed in the other sciences, where, having selected a few facts derived from experience, we divest them of all associations which are for the moment inconsequent, and proceed to derive by a course of reasoning, new relations which were not obvious in the premises; but there is this noteworthy difference that while in geometry and analysis the appeal

to nature is made but once and at the start, in physics new appeals to experience must often be made in the course of the reasoning, and the final relations are accepted only when they are not contradicted by the order of nature. And sometimes, even if the facts do not support the theory, it is still important to observe that the conditions of experiment may not have been so simple as the premises assumed and that the theory may still be true when the proper limitations are introduced. In the minds of certain men who are pleased to call themselves practical, a theory is exploded and to be completely rejected as soon as any discrepancy appears between the observed facts and the reasoned conclusions. To the physicist, however, some sort of theory or rational guide is so important and even necessary that a very imperfect or insufficient theory is preferable to none at all. He is not one of those who delight to hold up to ridicule false and abandoned theories, of which so many examples may be found in the history of physics, for he truly recognizes that though they now seem absurdly wrong, they nevertheless served a useful purpose as a temporary scaffold, without whose aid the more lasting structure might never have been erected. From familiar acquaintance with the imperfections of all experimental data, the physicist grows into the habit of holding his deductions subject to correction in the light of new or more accurate observations. Thus there arises the idea so well expressed by the late Professor Rowland, of degrees of truth or untruth.

> There is no such thing as absolute truth and absolute falsehood. The scientific mind should never recognize the perfect truth or the perfect falsehood of any supposed theory or observation. It should carefully weigh the chances of truth and error and grade each in its proper position along the line joining absolute truth and absolute error.
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> The ordinary crude mind has only two compartments, one for truth and one for error; indeed the contents of the two compartments are sadly mixed in most cases; the ideal scientific mind has an infinite number. Each theory or law is in its proper compartment indicating the probability of its truth. As a new fact arrives the scientist changes it from one compartment to another so as if possible to always keep it in its proper relation to truth and error.

The aim of physical science, according to the earlier writers, was the explanation of the phenomena of nature, *i. e.*, the tracing of occurrences to their causes or the proceeding by logical advance from the cause to the effect. The modern and more acceptable view, due perhaps in large measure to Kirchhoff, is that science aims to state in simple and easily reproducible language the order of the processes of nature. A phenomenon then has received its full explanation when we have presented to the mind a picture or a model in which we may reproduce at will the sequence of events which is observed in nature. All attempts beyond this to satisfy the sense of causation must be futile.

It is a well-known fact that the mind derives a certain pleasure in

tracing out similarities in very diverse things. One consequence of this process when systematically carried out was the early recognition of the fact that although the forms of nature were seemingly infinite and exceedingly complex, yet there was discernible throughout something like patterns that had been followed, as though nature were not infinitely varied after all. In anatomy, for example, the similarity in the structural form of fishes, birds and mammals was the subject of attention long before the doctrine of evolution furnished a satisfactory explanation for the resemblance.

Not less striking are the formal resemblances between the laws in widely differing departments of physics, so that, for example, if we have solved a certain problem in the distribution of heat in conductors, the same relation between the symbols furnishes the solution for an important case of electrical currents in conductors, as if the forms of the laws in nature were less complex than the phenomena, the most diversified things having been built up after exactly the same pattern.

The recognition of these far-reaching and surprising analogies is found to be most helpful. As Hertz once said, 'it seems as though an independent life and reason of its own dwelt in these mathematical formulæ; as if they were wiser than their discoverer, and gave out more than had been put into them.' But one caution is necessary. It must always be remembered that the analogies obtain between the relations and not between the things themselves. Thus we derive valuable mental assistance from the observation that electricity in its relation to potential behaves the same as an incompressible fluid with respect to pressure, but it is a great mistake to think that the thing electricity is like the thing water. Or, to take another illustration, the vibrations which give rise to the sensations of light occur with a rapidity which in an elastic solid would require an enormous rigidity; yet here, just as before, the analogy consists in the relations and not in the things, and those who try to think of an ether at once more rigid than steel and at the same time so tenuous that it produces no perceptible retardation of the planets show that they have missed the point of all analogies which is to furnish a mold in which we can cast our thought concerning the sequence of events.

In like manner, a law in science is now regarded simply as a convenient formula by which we express an observed correlation of properties or a uniformity in the order of nature, and the assumption that a law expresses a compelling and inviolate principle is wholly disclaimed.

The fundamental entities of physics, the ultimates in terms of which it is possible to express all other facts and phenomena of the science, are space, time, energy, matter, electricity and ether. It should, however, be said that it is doubtful whether there is necessity for both electricity and ether. There is a growing tendency at present to explain the properties of matter in terms of electricity.

The whole aim of the science is to state the phenomena of nature in terms of these quantities in the most exact language possible. From this point of view, a notable distinction in the kindred science of chemistry is at once apparent in that whereas chemistry introduces no new entity, it subdivides matter into upwards of eighty distinct ultimates called elements, thus enormously enlarging the number of combinations and phenomena with which it must deal.

Biology, again, while retaining all the postulates of physics and chemistry, introduces a new principle, that of life, whereby the phenomena to be treated become infinitely complex.

If we now recall that it is only the simplest phenomena of nature that can be formulated, it is at once obvious why chemistry and biology are so much more backward in their growth into exact sciences, the former being largely taken up with a description of the properties of different substances, while the latter can do little more than group together different living forms according to some principle of resemblance amid diversity. These differences make it evident that the character of mind best adapted for their investigation may differ somewhat in the different sciences, and also that the effects when taught will be more or less diverse. Different methods of presentation may likewise be found desirable.

In physics three modes of teaching are available, each of which is to be employed in conjunction with the others, each contributing an indispensable, but necessarily different and unequal, portion to the learner. They are (1) recitations upon a text-book, (2) demonstration of phenomena in lectures, (3) work in a physical laboratory. Now while there is nothing in these methods peculiar to the teaching of physics, it is important to observe that not only do the function and service of each method differ considerably in any one science, but that both the function and service of any method are widely different in different sciences. The function of the text-book is chiefly historical, *i. e.*, to record what progress in the development of the science has been effected by our predecessors; but in connection with physics it can not be too strongly emphasized that the science is not a bare record of observations upon natural phenomena. There is nothing more characteristic of the mental attitude of the physicist toward knowledge than the constant desire to answer not alone the question 'how?' but 'how much?' That is to say in other words, we begin to have adequate knowledge of a fact only when we can measure it.

A musician will say without hesitation that one composition is more classical than another. The insufficient and essentially subjective character of such knowledge is at once apparent if we press the question 'when is one composition twice as classical as another?'

Physics is not a bare record of facts, but a highly developed system

of quantitative relations between these facts and the order in which they occur. In this respect physics occupies the great middle ground between pure mathematics, in which the physical facts or axioms are few, and the principles or derived logical relations are the whole content, and chemistry in which the quantitative logical relations are few and the systematic arrangement of the facts forms the body of the science.

The discovery and the elaboration of the more important physical laws are justly reckoned among the grandest achievements of the human intellect. The character of a discovery, the persons to whom it was due, its philosophical importance, or bearing upon other parts of a science, the representation of the quantitative relations by symbols and the development of still other relations by the application of mathematical analysis, some facility in interpreting such short hand quantitative statements of physical principles, in short, the theory of physics, which is certainly the major part of this science, can best be inculcated by the use of a text-book and recitations. Surely any teaching which does not insist upon the philosophical and quantitative relations, however interesting and brilliant the experiments, or however entertaining the facts presented, or however it busies the student with laboratory exercises, does not teach the science of physics.

But granting that the theory of physics is the backbone of the science, there is no necessity of making it bare bone besides. The lectures should clothe it with flesh and blood. Physics is not an abstract science like mathematics, and the true physicist objects as much to making physics a mathematical gymnasium as he does to its appropriation as a toy for the kindergarten.

The experimental lecture affords the teacher an opportunity to present and explain to the student under the most favorable conditions the comparatively few important phenomena which he has not already met with. By favorable conditions it is meant that these unfamiliar phenomena often require the use of apparatus so delicate and costly that it is not to be trusted in the hands of any but an expert; or that the matter in question may be so overlaid and obscured by contemporaneous phenomena that the learner can recognize and follow it only with the assistance of a guide. Much also can be explained in the lectures as to the apparatus used for the determination of physical constants and the mode of conducting measurements which has no place in the ordinary text-book, and further the language may be less formal and the mode of presentation may embody much of the personal feeling and enthusiasm of the lecturer, both of which are entirely out of place in a text-book of the principles of a science. There will remain, however, a number of phenomena which, on account of their general minuteness, can not be satisfactorily exhibited in the lectures

and must be studied by the individual in the laboratory. In any elementary course they are relatively few in number, and even in a fully equipped laboratory are rarely shown to any but the most advanced students.

The value of the lecture demonstrations must again be emphasized in connection with the fact that a number of the most important phenomena, such, for example, as those of electricity, make no direct or at least no unmistakable appeal to our senses, and are apprehended only by some very ordinary occurrence like the movement of two objects in the field of vision. For example, a discovery of such immense importance as that of current induction by Faraday was evidenced to him only by the minute and momentary motion of a needle over a scale. And since throughout the whole range of physics the measurements are rarely direct, so that the interpretation of the reading of any apparatus is of more importance than making the reading, the first introduction to physical apparatus may often better be given on the lecture table than in the laboratory.

In turn with this brief discussion of the use of the text-book and the lecture demonstration the peculiar function of the physical laboratory deserves careful examination. We remark first of all that because experimental examination and dissection are essential to the teaching of biology it does not therefore follow that the laboratory teaching of physics is essential; nor because laboratory manipulation and observation are necessary to the teaching of chemistry does it follow that laboratory manipulation and observation must be necessary and indispensable to the teaching of physics. In such a statement there is not, however, intended the faintest suggestion that work in the physical laboratory is anything but useful and necessary, but rather to emphasize how widely the function of the physical laboratory differs from that of the chemical and biological laboratories. Physics is an exact science (though just what that means can be learned only in a physical laboratory) while biology is not so at all and chemistry is but to a limited degree.

Biology may be said to have formulated a few general laws, such, for example, as the law of biogenesis or the doctrine that life is generated by living beings only; the law of natural selection or the doctrine that the structure and function of any organism are the results of the survival of those members of a class which were best fitted to their surroundings; the law of prepotency which asserts that the probability of any organism approximating to its type increases with the number of its ancestors of that type. None of these laws contain any quantitative elements and consequently are never made the subject of laboratory measurements. As the rest of the science is for the most part a system of more or less rational classification of multitudinous forms of life,

or of the relation of the parts of an organism to one another there is obviously nothing in common between the observational deductions made in the biological laboratory and the quantitative measurements of the physical laboratory.

The divergence between the functions of the chemical and the physical laboratory is hardly less marked. While chemistry has irrefragable claims to designation as an exact science, the enumeration of the chief laws discovered up to the present is a simple matter and does not make a very imposing list. They are:

The law of the conservation of matter.
The law of constant proportion.
The law of multiple proportion.
The law of volumes or Avogadro's law.
The law of specific heats or the law of Dulong and Petit.
The law of periodic groups or Mendelejeff's law.
The law of electrolytic dissociation.
The law of isomerism.
The law of organic series.

It is, to say the least, a noteworthy thing that although these laws constitute the true claim of chemistry to be called a science and are moreover essentially quantitative in their character, practically no one ever thinks it necessary to the laboratory study of chemistry that students should carry out measurements looking toward even a rough verification of these laws, nor has the writer heard that the most enthusiastic advocate of the heuristic method has ever cajoled a student into thinking that he (the student) has discovered one of these laws by himself. The real fact which makes the laboratory study of chemistry a totally different one from that of physics is that the student meets even in the elementary stages a multitude of unfamiliar phenomena which can best be comprehended and learned by individual and intimate association with them, while there are altogether but two or three quantitative experiments which are available. In physics, on the other hand, the proportion is quite the reverse. The phenomena are, for the beginner, simple and entirely familiar, especially in mechanics, but the laws or quantitative relations are very numerous. Moreover, the comparisons made by the chemical student are for the most part qualitative in character; that is to say, they involve observation upon such things as the formation of precipitate, the evolution of a gas, a ready solubility or a change in color, and though the result may be more or less the particular amount is of no consequence. It is for this reason easy to arrange a laboratory course whose aim shall be to acquaint the student with such reactions, and we accordingly find him diligently employed in trying to find out what effect sulphuric acid will have on barium chloride or what silver nitrate has done to his fingers.

To spend the same amount of time in observing what happens when a brick is allowed to slide down a board or mercury is poured on a glass plate would be nonsense, and the writer of laboratory manuals feels himself driven to a verification, or study, as he may term it, of the quantitative laws. We thus too often find the student emulating Galileo in his discovery of the law of the pendulum. The absurdity of this attitude must be sufficiently obvious from the fact that in practise the student has always to be told what to discover and that it took the greatest men more than one laboratory exercise to find these laws originally.

It is at any rate true that the observation of physical phenomena for the purpose of mere acquaintance forms small part of any laboratory course, except in the more advanced parts of the subject, such, for example, as light and sound, and contrariwise those topics which demand such examination and acquaintance are commonly considered as too difficult of comprehension to be given to a beginner. From these considerations it must be evident that the usefulness of the physical laboratory can not be inferred from the benefits derived from the laboratory teaching of chemistry, but must be judged by a scale of values peculiarly its own. We have called physics an exact science. Now one of the uses of a physical laboratory is to make clear the meaning of that much misunderstood term 'exact.'

When Galileo was asked by the perplexed engineers why it was that water would not rise in their pumps to more than thirty feet he is said to have returned their question with another, 'Why does it rise at all?' To which they gave the current explanation, 'because nature abhors a vacuum.' 'Well then I suppose nature's abhorrence must cease at thirty feet' was the philosopher's doubtless knowing but evasive reply. That there is a limit to the elevation of liquids by atmospheric pressure and why is now understood by every educated person, but there are comparatively few who appreciate that exactness, like the schoolmen's *horror vacui,* ceases after a few significant figures.

The three fundamental magnitudes, time, length and mass, each possess some peculiar property in virtue of which they may be more accurately measured than almost any of the other physical magnitudes. Thus the length of the solar day is said to bear the ratio to the sidereal day of 1.00273791 to 1, an accuracy of one part in a hundred million.

The international kilogram has not been determined beyond 3/1,000 of a milligram, which implies an accuracy of one part in three hundred million.

The international meter has been measured in terms of the wave length of light to about one part in ten million, but such accuracy as that mentioned is attainable only in exceptional instances and enormously exceeds that within reach of ordinary careful work, which rarely extends to one part in ten thousand.

In the language of paradox, the physicist is exact because he knows how inexact he is. The phrase 'exact value' is a term with which many well meaning people deceive themselves and others. Every measure is imperfect. Mathematical precision is a fatuous term, except as qualified by the limits within which a statement is true.

In the face of some teaching a denial that physics is an experimental science seems almost to be justified. No law can be proved by one or by a hundred experiments. Suppose, as is sometimes done, that a student is given a bar, a knife edge and a couple of weights, and that he is asked to prove to law of the lever. He balances the bar, determines the weights, measures the lever arms and finds what? That the product of each weight by its corresponding lever arm is constant? By no means. For every time, and with whatever pains he has taken to secure accuracy, the product of the weight by its lever arm will be found different on each side, which proves, if literal interpretation of the figures is demanded, that the law of the lever is false. It is very important to recognize the fact that scientific laws are not proved by perfect corroboration of measurements. The proof of any law is of a negative character. Not even the law of gravitation nor the law of the conservation of energy is proved by any positive demonstration. The probable truth of any proposition is assumed from inability to disprove it. Whence it follows that there is nothing more fundamental to the correct understanding of the science of physics, or indeed of science in general, than the interpretation of measurements according to the theory of probabilities and a rational discussion of the inherent errors.

Now the difficult art of physical measurement can neither be taught nor learned apart from some sort of work in the physical laboratory. In this connection the student should be taught something concerning the different sorts of errors that may arise: (1) Errors of construction or of fluctuations in the measuring instruments. Many otherwise instructed people always start with the assumption that their instruments are correct. A little wholesome yet not unsettling distrust of makers' markings can be taught in a brief examination of scales and thermometers. (2) The limitations of the senses and observational errors may be clearly studied from a series of readings made upon almost any instrument having a moderate degree of sensitiveness. (3) Errors of definition, the personal equation, other constant errors and even out and out blunders demand full illustration and recognition. All these things may be taught from the simplest or from any available apparatus, and the knowledge of them is, in the writer's opinion, of more value to the apprehension of pure science than the exhibition or the so-called verification of any law that may be named.

In this insistence that the chief use of the physical laboratory is instruction in the difficult art of physical measurement, an art difficult on

the technical side, because of the patience and manipulative skill required, and difficult on the intellectual side because the comprehension of many measuring instruments is dependent upon advanced theory and considerable analytical power, it has not been forgotten that the laboratory may serve certain other though perhaps minor purposes. Just, for instance, as aid to distinct thinking may be rendered by the use of mathematical symbols and models, so also it will probably assist the unimaginative student to comprehend the laws under discussion if he can examine under his own manipulation the behavior of the apparatus which embodies those laws. Again there are certain phenomena which should be given the student for personal examination in the laboratory. Thermal phenomena involving the reading of thermometers; the passage of a liquid through the critical state; the study of compound tones; the observation of spectra, diffraction and polarization of light waves are examples of the kind of phenomena which require laboratory instruction. The number, however, of such exercises which appear even in the manuals of a college course is insignificant.

The pedagogists who, either with or without any definite knowledge of exact science, are perfectly sure how it ought to be taught assert that the first step in all good teaching is an appeal to the observing powers. "It is a cardinal principle in modern pedagogy that real and adequate knowledge of things can be obtained only in the presence of the things themselves," says one. Assuming that this is as true as the author thought it to be, it is but a half truth, the other half being that the presence merely of the things can not impart any really adequate knowledge. A boy, for instance, might watch the motion of the planets till he was gray without ever learning the first thing about gravitation or the solar system. Facts are but the raw materials of knowledge upon which the reasoning faculties must be exerted in order to extract the hidden principles of nature.

A writer of a well-known series of text-books has adopted as a sort of motto for his pupils, 'Read nature in the language of experiment.' One can not crtiticize an oracular utterance of this sort for the reason that it is not possible to say just what its author had in mind. If it is meant that empirical knowledge derived from the observation of detached facts and not brought into accordance with other facts by means of a hypothesis concerning their relation is sufficient for one to divine the laws of nature, we must certainly dissent. The language of experiment is in general a most difficult one to read, since, as we have been insisting, the measurements are in the great majority of cases indirect and to be interpreted only by tracing through a train of complex relations the consequences of the things observed upon some hypothesis whose truth it is desired to test.

Turning now to the more technical side of the science, it is interesting to notice how this indirect character of most physical measurements determines not only the mode of measurements in general, but their precision as well. A measurement, we say, consists in the comparison of any concrete quantity with a definite portion of the same physical magnitude selected as a unit. In a few instances, the comparison is direct, as in the determination of a length by a divided scale, but in the great majority of cases the numerical measure of a quantity is computed by the aid of a relation between other magnitudes which may be more directly, or, at least, more simply, measured. The content of a sphere, for instance, is not determined by successive applications of the unit-cube to the enclosed space, but by first measuring its diameter with calipers and then calculating the volume by the known geometrical relation between the two. Or, to cite another illustration, the direct comparison of a given velocity with the assumed unit of velocity would be a troublesome thing, involving, if they were not very nearly equal in amount, the repeated subdivision of the one or the multiplication of the other. To avoid this, we define the measure of velocity to be the distance traversed per second, and the measurement may then be effected by the simpler process of measuring separately a distance and a time.

In making comparisons, one of the senses must ultimately be appealed to as the judge of the coincidence of two values, but in forming this judgment apparatus is introduced of such sort that the comparison shall contain the least amount of personal bias or subjective impression, thus eliminating as far as possible the psychological element, since the thing desired is a physical equality rather than a psychological one. The former must indeed involve some form of the latter, but equal psychological impressions do not entail equivalent causes. It is a remarkable fact that practically all exact measurements have been reduced to the judgment of the coincidence of two lines by the sense of sight. This universal preference of the eye is probably due not so much to the greater freedom of this sense from illusive deception, as to its unique relation to geometrical space. Various of the other senses are able to distinguish and even to compare degrees or amounts of differences in the sensations peculiar to them, *i. e.*, they are able to estimate a kind of interval or difference in these sensations. The ear in connection with memory, is able to distinguish an interval of time between two successive taps as small as one one hundredth of a second, which is perhaps ten times as well as the eye can do with successive flashes. In another kind of sensation peculiar to hearing, namely pitch, the ear without the aid of beats easily distinguishes sounds whose frequencies are in a smaller ratio than 25/24. Similarly the muscular sense will under proper conditions distinguish an increase in weight of

about one per cent., and it is said that experts can distinguish the difference of a fraction of a degree centigrade by the temperature sense alone. Now while the other senses may distinguish two or more kinds of extension, as, for instance, pitch and loudness in the case of hearing, vision is the only sense with quantitative perception in which the extensions are identical in every respect except in their relation to directions, thus giving a field of vision so-called within which individually different marks may be compared. The eye is capable of judging the coincidence of two abutting lines to one minute of arc, which is a more sensitive determination than can be secured from any other sense perception.

The preceding pages may have conveyed the impression that the study of physics is a stern and difficult one. While there was no wish on the writer's part to magnify the difficulties of this most interesting science, it was a definite part of his plan to show that the proper teaching of physics does not consist in the acquisition by the pupil of first-hand knowledge of phenomena; neither does it consist in trying to implant a spirit of inductive reasoning whereby a student is led to divine the great laws of nature as a discoverer; least of all is the obedient following of directions set down in a manual or given by an instructor the study of physics. That alone is true and successful study which cultivates logical power in dealing with phenomena, gives a tenacious hold upon what is known and adds at least something of how the field in present possession of the science was explored and occupied.

ENGLISH HERBALS.

BY AGNES ROBERTSON, B. Sc.,
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IN the fifteenth and sixteenth centuries there was a renewal of the scientific spirit, as well as the more obvious revival in art and letters of which we commonly speak as the Renaissance. Among the most striking of the many visible fruits of this revival were numerous herbals, in which all the plants then known were enumerated, described and often beautifully figured. The earliest English example with which I am acquainted is a small, black-letter, anonymous volume published in 1525. The title is 'Here begynneth a newe mater, the whiche sheweth and treateth of ye vertues and propeytes of herbes, the whiche is called an Herball.' There are scarcely any descriptions of the plants, but long and elaborate dissertations on their virtues. Even such a commonplace weed as the plantain is credited with considerable powers: "For heed ache take Plantayne and bynde it aboute thy necke and ye ache shall go out of thy heed." Of rosemary we read: "Take the flowres and make powder thereof and bynde it to the ryght arme in a lynen clothe, and it shall make thee lyght and mery. Also boyle the leves in whyte wyne and washe thy face therwith, and thou shall have a fayre face. Also put the leves under thy beddes heed, and thou shal be delyvered of all evyll dremes. Also make thee a box of the wood and smell to it, and it shall preserve thy youthe."

In the following year was published one of the most famous of the old herbals, 'The Grete Herball which geveth parfyt knowlege and understandyng of all maner of herbes and there gracyous vertues.' This includes in addition to plants, descriptions of a number of substances, such as gold, silver, asphalt, starch, vinegar, butter, honey and the lodestone! It contains delightful prescriptions for healing all manner of ailments. For instance, Apium 'is good for lunatyke folke yf it be bounde to the pacyentes heed with a lynen clothe dyed reed the moone beynge in cresaunt in the sygne of Taurus or Scorpion in ye fyrst parte of the sygne, and he shal be hole anone'; and as a cure 'for werynesse' we read, "To them that be wery of goynge gyve to drink a dragme of the powdre of Bethony with warm water and an once of orimell." The following statement gives an inkling of the condition of plant-geography at the time: Balsam 'is founde towarde Babylon, in a field whereas VII welles or fountaynes be, and is carried from thens'!

Nearly thirty years later, Henry Lyte translated into English the famous Dutch 'Herbal' of Dodoens. Lyte was an Oxford student who traveled in foreign lands and collected a number of rare plants, and on his return to England founded one of the first botanical gardens in this country. The title of his translation is 'A niewe Herball, or Historie of Plantes: wherein is contayned the whole discourse and perfect description of all sortes of Herbes and Plantes; their divers and sundry kindes: their straunge Figures, Fashions, and Shapes: their Names, Natures, Operations, and Vertues.' The book is most beautifully illustrated, and contains the records of some capital pieces of observation, but it is startling every now and then to meet with statements like this, 'Alysson hanged in the house, or at the gate, or entry, keepeth both man and beast from enchantments, or witching,' and 'The seede of the garden Larckes spurre dronken is very good agaynst the stinging of Scorpions, and indeede his virtue is so great against their poyson, that the herbe throwen before the Scorpions, doth cause them to be without force or power to do hurte, so that they may not move or sturre, until this herbe be taken from them.'

At the very end of the sixteenth century appeared the best known of all the herbals, that of 'John Gerarde, of London, Master in Chirurgerie.' Gerarde seems to have been an unscrupulous plagiarist, for he bases his herbal, quite without acknowledgment, on Priest's translation of Dodoens's collected works. Also of his eighteen hundred wood-cuts, less than twenty are original! So, altogether, his great reputation seems to have been built on somewhat frail foundations. Still he appears to have been a first-rate botanist, and in his garden in Holborn he cultivated more than a thousand different kinds of plants. I can not help thinking how delighted he would have been with a modern botanic garden, and particularly with one of the modern collections of insectivorous plants. For he gives a little figure of Sarracenia, the pitcher plant, copied from Clusius, who says he received the drawing with one dried leaf from an apothecary of Paris, who himself received it from Lisbon. Gerarde reproduces the figure 'for the strangeness thereof,' and in the 'hope that some or other that travell into forraine parts may finde this elegant plant, and know it by this small expression, and bring it home with them, that so we may come to a perfecter knowledge thereof.'

Later on the fashion set in of leavening botany with astrology. The best known exponents of this kind of pseudo-science are Culpeper and Turner. Nicholas Culpeper seems to have been afflicted with boundless self-conceit; the following is a sample of his bombastic style: "To find out the Reason of the operation of Herbs, Plants, etc., by the Stars went I, and herein I could find but few Authors, but those as full of nonsense and contradiction as an egg is full of meat; this not being pleasing, and less profitable to me, I consulted with my two Brothers, Dr. Reason, and Dr. Experience, and took a voyage to visit

my Mother Nature, by whose advice, together with the help of Dr. Diligence, I at last obtained my desire, and being warned by Mr. Honesty, a stranger in our days, to publish it to the World, I have done it." Culpeper seems to have been absolutely saturated with his astrological notions; he tells us that 'seed sowed at the wane of the Moon, grows either not at all, or to no purpose'!

Returning to the earliest herbals, we find that the idea of natural relationship between plants, or even of the necessity of any sort of classification, is scarcely existent. The anonymous Herbal of 1525, and the 'Grete Herball' are both arranged alphabetically. But the 'Grete Herball' contains the germ of a classification of the fungi—a classification of the most charming simplicity! "Fungi ben mussherons. There be two maners of them, one maner is deadly and sleeth them that eateth of them, and be called todestoles, and the other dooth not." Exactly fifty years after the publication of the 'Grete Herball,' Lobel's 'Herbal' appeared, and from it we gather that during this half century the idea of natural affinity had been in a sort of dim instinctive fashion getting hold of men's minds. He describes in succession rushes, grasses, bulbous plants, orchidaceous plants, crucifers, composite plants, etc. The arrangements adopted by Dodoens and later by Gerarde are similar to that of Lobel, but slightly more natural. Parkinson in 1640 gives a more elaborate classification, and though it seems very primitive when judged by the standard of the present day, especially as regards the stress laid on the 'virtues' of the plants, yet it shows that great progress had been made since the publication of the earliest herbals. He divides all plants into seventeen classes, some of which are quite satisfactory, while others, such as No. 14, which includes 'Marsh, Water and Sea Plants, and Mosses and Mushrooms,' are a trifle too comprehensive! There is something charmingly naïve about the titles of his fifteenth and seventeenth classes. These are 'The Unordered Tribe' and 'Strange and Outlandish Plants.'

Early in the next century Linnæus was born. A vast mass of information had been accumulating for two hundred years, and it needed a luminous intellect like his to reduce it to order. As the fruit of his labor we have his marvelous 'System,' in which he followed a much earlier writer, the Italian botanist, Cesalpinus, in attributing the chief importance to the organs of fructification. The day of the herbal proper may be said to have closed with Linnæus and thenceforward botany proceeded on more strictly scientific lines. The subject sprang into fashion in his time in the most astonishing way, probably owing to the easy method which his 'System' offered of tracking down and identifying plants—from the chosen pursuit of a few enthusiasts it became the heritage of the many—it was dubbed the 'loveliest of the sciences,' and 'recommended especially to ladies, as a harmless pastime, not overtaxing to the mind.'

THE GEOLOGY AND GEO-BOTANY OF ASIA.*

BY PRINCE P. KROPOTKIN.

THE time has not yet come when the geological history of Asia can be written in full. It appears, however, that, with the exception of a marginal zone in the south, which belongs to the Himalayan upheavals, the great plateaus of east Asia are built up of crystalline unstratified rocks, granites, granitites, syenites and diorites, as well as of gneisses, talc and mica-schists, clay-slates and limestones, which all belong to the Archean formation (Huronian, Laurentian, Silurian and partly Devonian). They thus can not have been submerged by the sea since the Devonian epoch. The higher terrace of the plateau of Pamir and the plateaus of the Selenga and the Vitim are formed only of Huronian and Laurentian azoic schists; even Silurian deposits—widely spread on the plains—are doubtful on the plateaus. Their upheaval must date accordingly from an earlier age, and they must have been a continent during the Devonian epoch, while parts at least of the lower terrace were under the sea at that period. During the Jurassic and Tertiary periods immense fresh-water basins covered the surface of those plateaus; they have left their traces in Jurassic coal-beds, and in Tertiary sands and conglomerates, these latter appearing in mighty layers on the borders and slopes of the plateaus. The chains of mountains which fringe the plateaus along their northwestern and southeastern borders are of the same ancient geological origin. They rose above the Carboniferous, Triassic, Chalk and Jurassic seas which covered what are now the lowlands and lower terraces of Asia; the upheaval of these chains has, however, continued throughout these epochs, so that in the outer chains of Asia we see Carboniferous and younger deposits, up to Tertiary, lifted up to great heights. The same is true of the border-ranges along the southwestern border of the great plateau of east Asia, namely, the Himalayas, which were lifted during the Tertiary age, while at their northern foot, on the surface of what is now the surface of the plateau, traces of Triassic deposits seem to have been found near Lhasa. Carboniferous deposits are met with in Turkestan, India and western Asia; while in eastern Asia the numerous coal-beds of Manchuria, China and the archipelagoes are all Jurassic. As to the age of the plateaus of western Asia, it remains unknown at the present time.

* From an article in the March number of *The Geographical Journal*.

What are now the lowlands of Asia must have been widely submerged by the seas of the Tertiary period, as also those of the Quaternary (Post-Pliocene) period. During this last period, the whole of the lowlands of northwest Siberia were under the sea, as far as the fiftieth degree of latitude, a broad gulf of the Arctic Ocean penetrating at the eastern foot of the Urals as far as the watershed which now separates the basin of the Obi from the Aral-Caspian Sea. At the same time there are no traces of that sea on the high plains of east Siberia, which were only intersected by several narrow elongated gulfs of the ocean. The moistness that thus ensued permitted glaciers (which are wanting now throughout the middle parts of east Siberia and Mongolia) freely to accumulate, so that the whole of the upper plateau and its border-ridges were under a mighty ice-cap. Immense glaciers, like those of the Alps and Jura, covered also the alpine regions. How far glaciation extended over the plateau of Tibet and in China still remains unsettled. In Turkestan and Siberia immense accumulations of loess fringe the alpine regions; while in China they cover immense tracts, and are the most fertile regions of Asia.

Many important changes in the distribution of land and water have been going on in Asia since the Glacial period, and even during historical times. Since the Aral-Caspian Sea became isolated from the ocean, its desiccation, as well as that of the numberless lakes which dotted the surface of Asia during the Lacustrine (Post-Glacial) period, has proceeded with a rapidity which may be guessed from the very rapid rate at which the process has been observed to go on in Siberia during the last hundred years. All Asia bears unmistakable traces of having been covered during the Lacustrine period with numberless large and small lakes, which have now disappeared, not in consequence of the action of man, but in consequence of some general causes affecting the earth's surface since the last Glacial period. The process is still more accelerated by the rapid upheaval of the continent—the whole of the Arctic coast, as also most of that washed by the Pacific, the Mediterranean, the Red Sea and parts of the Indian Ocean, being in a state of gradual elevation, while the few areas where traces of subsidence have been noticed are very limited. The influence of the desiccation of Asia has been felt even during historical times, and the migrations of the Ural-Altaians, Turks and Mongols will probably be best explained if this change in the condition of central Asia be taken into account; while the same circumstance explains the present nearly desert state of those regions which were the cradle of European civilization.

Volcanoes play an important part in Asia's geology; no less than 122 active volcanoes are already known in Asia, chiefly in the islands of southeast Asia, the Philippines, Japan, the Kuriles and Kamchatka,

as also in a few islands of the Bay of Bengal and Arabia, and of western Asia. Numerous extinct volcanoes are found, not only in the same regions, but also in the Caucasus, on the plateau of Armenia, in east Tian-shan, in the northwestern border-ridges of the high Siberian plateau, and in the southwest of Aigun, in Manchuria (the Uyun Holdontsi region). An immense zone of land was covered with basaltic lavas during the early Tertiary period (or Cretaceous?) along the northwestern border of the high plateau of east Asia, and vents through which scoriæ were ejected, forming small cones of ejection, are still seen on the Mongolian and Vitim plateaus, as well as in the Sayans. Earthquakes are frequent, especially in Armenia, Turkestan and around Lake Baikal.

With the rich botanic materials which we are already in possession of, it would be extremely interesting to make a picture of the distribution of the different floras of Asia upon the surfaces of its high and lower plateaus, their border-ranges, the alpine zones, the high plains, and the lowlands. It would then appear how much these orographical divisions can help us to find out the true distribution of floras, which botanists have hitherto tried to bring into accordance with zones that were traced either along the degrees of latitude, or according to the basins of the different rivers, without taking into account the great orographical divisions and the differences of altitude, which mostly run in diagonal directions. Thus, to take only one example, the Great Khingan is the most important botanical boundary which is found all over Siberia and Manchuria. When one crosses this border-range and goes down its steep slope towards the east, one sees that in one hour, or maybe in half an hour, quite a new flora—Manchurian—takes the place of the Siberian flora; and one notices the appearance of trees, which strike even the most ignorant in botany, because these trees have not been seen before, while the traveler crossed Siberia over a distance of several thousand miles. One sees also how the Manchurian flora endeavors to spread westwards along the valleys of the Upper Amur and the Argun. Another important botanic boundary is the escarpment of the upper plateau, that is, the border-range of the Yablonovoi. This escarpment separates the Daurian flora from the Siberian, properly speaking, as sharply as the Great Khingan separates the Manchurian flora from the Daurian.

The Little Khingan will, I am inclined to think, also appear some day as another interesting botanic boundary between the Manchurian flora and the flora of the Pacific littoral. It is also quite certain that in central Asia, in the Gobi, in India and in western Asia, one could arrive at most interesting botanical generalizations by establishing the connection between the orographical and the botanical data; it is sufficient to mention here, as an instance, the delimitation of botanic

regions in the Caucasus lately made by Russian botanists, who have shown that the Pontic range (that is, the border-range of the Armenian plateau) is an extremely important botanic boundary, or the remarks of M. Novitskiy concerning the flora of the Karakoram plateau.

The immense region which is usually represented on geo-botanic maps under the name of Eur-Asian boreal region, and which is bounded on the south by a line traced from the Black Sea to Lake Baikal and thence to the Upper Amur and to the Sea of Okhotsk—this region has not the uniformity which one would be inclined to attribute to it by considering the map only. While it is quite certain that plants easily spread from west to east—from Russia to the lowlands of western Siberia—they spread also with the same facility from the southwest to the northeast along the high plains, the alpine zone, the border-ranges and the plateau itself. Consequently, the flora of Siberia itself can already be subdivided quite naturally into a number of distinct regions running southwest to northeast, and not west to east. Thus we see, for instance, the cedar-tree (*Pinus Cembra*) spreading along the highest parts of the northwestern border-range of the high plateau, from the Altai to the Lena. We find again the same vegetation on the high plateau in northwestern Mongolia, round Lake Kosogol and the Upper Vitim. The vegetation of the high plains of the Altai offers again a great analogy with the vegetation of the high plains in the west of Lake Baikal (the Minusinsk flora being an intermediate link between the two), and the Transbaikalian flora in the east of the Yablonovoi has very much in common with the flora of the Gobi.

As soon as the Amur emerges from the high plateau, in which it has excavated a deep valley, we find on its banks representatives of the Chinese and Japanese flora under the very same latitudes where we find the Siberian flora further west. And it appears from recent explorations that even round Lake Balkhash, and at the foot of the Tian-shan, vestiges of the European-Siberian flora have maintained themselves on the best-watered slopes. The lines of propagation of plants along the degrees of latitude are thus completed by lines of propagation having an oblique direction, from southwest to northeast.

The next zone which is marked on our botanical maps is the zone of the Steppes, which spreads from the prairies of south Russia through the Aral-Caspian depression and the middle parts of the high plateaus.

Western and eastern Asia, including various separate desert regions (the Han-hai, the Gobi, the dry parts of Inner Arabia, of Persia and of northwest India). However, this immense region ought to be subdivided, for central Asia alone, into at least four distinct regions, namely, the Aral-Caspian flora, the Tian-shan, the Tibet and the Mongolian flora.

The flora of the regions situated on the east of the high plateau,

including China, Manchuria and Japan, must be considered as a counterpart of the Mediterranean flora. The oak reappears as soon as we cross the eastern border-ridge of the plateau, which is the Great Khingan; so also the walnut tree, the lime tree, the hazel and the myrtle, while several new species of poplar, willow, acacias and many others make their appearance. The forests, consisting of a very mixed vegetation, where southern species meet with northern ones, become really beautiful; while in Japan a variety of species of pine and the reappearance of the beech add to their beauty. A rich underwood of lianas, ivies, wild vines, roses and so on renders the forests quite impassable, especially in the littoral region, which is submitted to the influence of the monsoons. In the lower parts rich prairies cover immense spaces, the grass vegetation becomes luxuriant, and in the virgin prairies of the Amur man and horse are easily concealed by the grasses of gigantic size. Rice and cotton are cultivated in the southern part of the region. However, this region is too vast, and has too many different aspects, to be considered as one single region, and ought to be subdivided into three sections—the Chinese flora, that of Manchuria and the Okhotsk littoral.

A striking change in the character of the vegetation is also seen, as we now learn from recent exploration, at the southeastern extremity of the high plateau of Asia. The traveler who comes from Mongolia and has crossed the Kam region of eastern Tibet finds, as soon as he has penetrated into the region of the tributaries of the Blue River and Mekong, quite a new world, both vegetable and animal. The very fact that the 12,000-feet-high plateau is deeply excavated by the valleys and canyons of the great rivers, and that this part of the plateau is submitted to the influence of the monsoons blowing from the southwest, is sufficient to give quite a new character to the vegetation, which may be described as a mixture of the Chinese and Indo-Chinese floras.

In the Caucasus the rich vegetation of the wet portions of the country, situated between the main chains of the Caucasus and the Pontic chain, belongs to the Mediterranean flora of western Europe. As to the flora of Asia Minor, it combines the species of southern Europe with those of north Africa, as we find there evergreen oaks, the laurel-olive tree, the myrtle, the oleander, the pistachio tree and a great variety of bulbous plants.

These few remarks indicate how much the task of the geo-botanist would be facilitated if he took into consideration the great features of the orography of Asia and the orientation of the main orographic divisions. The same must be said with regard to the fauna of Asia. It would be impossible to understand its distribution if we did not take into consideration, as has been indicated by Syevertsoff, the spreading of many species from the southwest to the northeast along the plateaus

and the plains. It may thus be said that the high plateau of Asia has its own fauna, so also its lower terrace, and also the lowlands of the deserts and those of the prairies.

*   *   *

If the theory of Dana is approximately correct, then the gradual growth of the Asiatic continent, as well as its present shape, can be very well explained. During the Primary epoch, Asia consisted only of the high plateau, which had the shape of a South America, directed by its narrow point towards the Behring Strait. (Was not the North Pole in that direction at that time?) On the line of division between what was then the continent and the oceans which surrounded it at that time, in consequence of the oblique thrust of which Dana speaks, the border-ranges must have been formed all along the fringe of the high plateaus, while a succession of parallel mountain ranges, resulting from as many foldings of the strata, were formed round the continent, just as the islands of Formosa, Japan, and so on, are now lifted all round the continent of Asia in a series of curves indicated by Suess. Later on, when the lower Mongolian terrace of the plateau emerged in its turn from the ocean, the formation of mountains was continued along its borders. It was then that, in all probability, the border-ranges of the second terrace (Great Khingan, etc.) and the alpine zone which fringes these border-ranges were formed.

A similar formation is also found, but on a much smaller scale, along the fringe of the third terrace—the terrace of the high plains; but the arrest of upheavals was not sufficiently long at this stage, nor was the difference of level between the high plains and the bottom of the ocean sufficiently large to generate the high border-ranges such as we find along the fringes of the plateau. And finally, during the recent periods, a series of littoral chains has been lifted up, and is being lifted up still, all along the present coasts of the Pacific Ocean. That these chains are not generated in straight lines, but have a crescent shape, as has been suggested by Suess, is pretty correct, and it must also be remarked that the border-ranges of the plateau also are not quite straight lines. We see, on the contrary, that straight lines are intermingled with crescents, and when I speak of chains of mountains having a direction from the southwest to the northeast, or from southeast to northwest, I only mean that such is the general direction of the chain, without pretending to say that the chain follows necessarily a straight line. Sometimes the line is nearly straight, or it follows a great circle of our globe; this last case is very frequent, but sometimes it also has the shape of a curve. It thus appears that the theory of Dana, completed by the study of erosions which took place during an extremely long succession of ages on a grand scale, and the generalizations concerning the orography of Asia, which are expounded here, stand sufficiently in accordance for mutually confirming each other.

THE ROYAL PRUSSIAN ACADEMY OF SCIENCE AND THE FINE ARTS. BERLIN.

BY EDWARD F. WILLIAMS,

CHICAGO, ILL.

III. From the death of Frederick the Great to the death of Frederick William III., 1786–1812.

NOTHING was of more importance to the academy during this period than its change from a French to a German institution. This change was brought about in part under Frederick William II. (1786–1797) by his minister Hertzberg who had long been a member of the academy, and who under the new king became its curator and so remained till his death in 1795. The change was made complete, in form at least, by the adoption, in 1812, of what is known as the Humboldt brothers' statute. At this time the academy was ruled by a new spirit. It was under the control of men like the Humboldts, Niebuhr and Schleiermacher, who sought to realize through it the aims of Leibniz, its founder. The new spirit was manifest in all its departments; in those of philosophy, history and philology, as well as in those of science. Together with a growing respect for the ability of German writers and thinkers there was an increasing love for the fatherland, a conviction that patriotism was as worthy of cultivation as the new fields of learning which were opening on every side.

Hertzberg, though somewhat arbitrary in his methods, saved the academy from threatened dissolution. He was in many respects a very remarkable man. As a statesman he sought to carry out the views of Frederick the Great. A true son of his century, a scholar of no mean rank, skillful as a historical student in the use of original documents and deeply interested in the work of the academy, he determined to reorganize it on the basis of the old German spirit. If he cared little for Goethe and his cosmopolitanism and failed to appreciate Herder at his true worth, he did not fail to see what an opportunity the academy might have for directing the thought and life of the German people. In his hands the curatorship became an office of power. In order to weaken French influence in the academy during his first year as curator he added fifteen Germans to its eighteen active members, and secured for foreign membership men of the first rank like Gasse of Breslau, Eberhard of Halle, Kant of Königsberg, Magellan, Volta, Wieland, Heyne and Herder. His only mistake was in not bringing these men to Berlin and associating them with the resident German element

in the work of the academy. If the French element regretted its loss of power in the academy, it made the best of it and continued to contribute to its publications. Ceasing to be minister in 1791, Hertzberg continued to work for the academy until his death. In some of his political views he was a liberal, and in papers read at the regular sessions of the academy, and afterwards printed, he did not hesitate to compare the advantages and disadvantages of monarchical and republican forms of government. After the French Revolution it is not strange that kings and their sympathizers became suspicious of his opinions. Subsequent to his death, during the remainder of the king's life the academy did very little. In this reign only three volumes of 'Memoires' were published. In 1795 the French language was again made the medium of discussion in the academy. It was voted also that for five years no new members should be received. Alexander von Humboldt characterized it as 'a hospital in which the sick slept better than the well.' For the indifference of the German members there is little excuse. They were silent when they ought to have spoken, cowardly when they should have been brave. Greatly indebted to Hertzberg for the influence he had exerted in the days of his power on behalf of the academy, its members took no notice of his death, nor made any reference to him in official publications. It sank so low as to countersign an order of the cabinet against Kant, and ceased to be a center for free thought and free speech. It seemed to be more at home in exercising the duties of censorship than in increasing and diffusing knowledge. It is not strange that men who sympathized with Mendelssohn united with him in organizing the Philosophical Society, which soon became a center for the new thought and life of the time, where men who cared to discuss questions of the day could meet in safety. From 1783 to 1798 this society filled a great place in the Prussian capital.

Under Frederick William III. the academy was managed by the Humboldts and Niebuhr. At the beginning of his reign the new king was supposed to be in favor of progress and freedom in thought and speech. But after his first year on the throne he became a reactionary, and was not unwilling to exercise his prerogative as censor. He wished the academy to confine itself to studies and investigations which would be of use to the nation. Neither he nor any of his ministers would aid it on other conditions. The cultus minister desired its assistance in improving the public schools. There were protests against the old rules introduced by Hertzberg. An order of April 9, 1798, cut deep into the life and privileges of the academy. The presidential office was left vacant. Only such work as was of immediate advantage to the people was approved. Borgstede was put into the academy by the king, as his representative and to look after its interests. Fortunately he had a real desire for the growth of the academy and did what he could for

it. Its membership was reduced by order of the king to six and a director for each of the four classes, or twenty-eight in all. From 1799 to 1806 there were no important changes in either the constitution or the by-laws of the academy. But while wars were waging and political storms were brewing its members led a quiet and peaceful life and made some contributions of real value to the learning of the world. The French Academy at this time was far in advance of that in Berlin in scientific work.

But there were thoughts of a university in Berlin even in the dark days of the French invasion, and as early as 1800. The observatory was rebuilt at the expense of the academy. Wulff of Halle was induced to come to Berlin and work in it. In 1800 Humboldt, then absent in South America, was made an honorary member, and on his return to Berlin in 1805 he became an active member. Kotzebue was received in 1800, and Thaer was induced to leave Hannover for Berlin in order that he might join the physical class of the academy. He was the author of a system of law which proved of great value for Prussia. Professor Thalles of Bonn, a famous mathematician, was also brought to Berlin and received into the academy. As early at 1788 Johannes von Müller, the well-known historical writer, became a foreign member, though afterwards he made friends with Napoleon and turned his back on his country. Perhaps it was on account of aversion to philosophical opinions which their author deemed epoch-making, as well as to dislike of the man, that Fichte, though brought forward by very influential persons, was rejected as a member of the academy. But he was permitted to deliver his lectures in the winter of 1804–5 in its hall. These lectures were a kind of negative preface to the 'Reden,' or addresses to the German people, made a year or so later, which did so much to arouse and unite them in their struggle for liberty. Alexander von Humboldt proposed and secured the election of Ermann, the physicist, and of von Busch, the geologist, as extraordinary members of the academy. Not long after Buttmann, the grammarian, became an active member, and with him, by order of the king, Count Lahndorff, the poet. Before the war began on July 31, 1806, *i. e.*, prior to the disaster at Jena, Goethe, Cuvier, Brooks and Hendenberg were made honorary members.

The proceedings of the academy the next six years were fundamental for its future life and activity. In the two Humboldts it seemed as if the spirit of Leibniz had revived, as if they possessed his extensive general knowledge, his love for the sciences, his power of organization, his leadership and his ability to meet and overcome difficulties. There were other able men in the academy, but at this time the two Humboldts were its leaders. The defeated king was at Königsberg, whence he made known his wish that Prussia seek to recover what had been

lost materially through improvement in methods of education and a deeper and truer spiritual life. Neither he nor his advisers would admit that there was no future for their suffering country. In spite of losses of territory and of the choicest specimens of art and sculpture in the museums, in spite of the fact that even the academy had been robbed of its most valuable treasures, it was in this period that the University of Berlin was founded and men of the highest attainments obtained as professors and also as members of the academy. King and people seemed to be determined to prove to the world that the spirit and pride of Frederick the Great still ruled the Prussian heart. There were some who desired a union of the university and the academy, but of this plan the king did not approve, although he was not averse to a very close connection between them. So far as they had ability for it, he wished professors to work in the academy as well as in the university.

Upon the whole, the king favored the academy, and although he did not relieve it as it requested from the burden of Lambert's presidency, he gave it the four secretaries it asked for, one for each class, and allowed them to direct its work. Before the royal decree establishing the university had been issued, Schleiermacher, Wulff, Schmalz and Fichte, through their lectures, had really laid its foundations and begun its work. At about this time (1810) Alexander von Humboldt proposed a good many changes in the constitution and rules of the academy, most of which were adopted. These changes sought to promote equality among the members and favored the reception of men of high attainments rather than of large wealth or political influence. All the desired changes, however, were not adopted until they were incorporated in the constitution of 1812.

William von Humboldt became an honorary member of the academy in 1806, when he was serving the government as ambassador in Rome, and an active member in 1810. His entrance speech, limited to a few words, is said by those who heard it to have been delivered in such words as he only could use. As minister of instruction he had rare opportunity, which he did not fail to embrace, to work for the interests of the academy. It needed all the aid he could give. Financially it was in great straits. Although Napoleon offered to send plaster casts of the objects of art the French army had carried away, there was no money with which to pay the cost of transportation. Expenses as planned by its members would have been nearly $25,000 a year. The request for a grant to this amount, though some of the older members looked grave and shook their heads, was not at all extravagant, considering the salaries the academy had to pay and the fact that it had to provide for the support of the library, the observatory, the botanic garden, the scientific collections, the care of the buildings, as well as to meet many unexpected miscellaneous expenses. At this time it was

asked to turn over to the government the 'Calendar' monopoly it had so long enjoyed. This it was not inclined to do until the order of the king rendered it imperative.

In 1811 William von Humboldt was sent as ambassador to Vienna, but his views and plans for the academy were left with his friend Nocolovinus, who secured their adoption and their incorporation into the constitution and by-laws of 1812. This was the last year in which the reports of the academy appear in French. The income actually obtained was a little less than $7,000, but the expenses of the institutions which it had previously met were now met from other funds. The new statute was confirmed by the king on January 24, 1812, and the next year the last volume of the 'Memoires,' bearing the date of 1804, was published. In offering prizes Latin and French were still used, but henceforward the language of the academy, for its publications as well as its discussions, was German.

In its management there was now neither president, curator, nor director. The management of its work was in the hands of four secretaries. There were the usual classes of members, active, foreign or honorary, and corresponding. It was decided that only twenty-four foreign members should be chosen, eight for each of the scientific classes and four for each of the other two classes. There was no limit to the number of corresponding members. Regular sessions were henceforth held every Thursday afternoon, and every fourth Monday each class had an extra meeting in order to render its special work more effective. There were to be three public meetings each year, one of them in July in honor of Leibniz, another on the king's birthday, the third on January 24, or Frederick's day. Each member was required to read at least one paper every year until he had been in the academy twenty-five years; after that time, at his own pleasure. The subjects were to be assigned by the class to which the member who was to write belonged. Each class was permitted to choose its own members, subject to the approval of the entire academy and of the king. Each volume of the proceedings or transactions, was to be divided into four parts, so that reports of the work of each class might appear together.

In 1811–12 twenty-four foreign members were chosen, among them William von Humboldt, now residing in Vienna, Jacobi, the philosopher, and Professor Dugald Stewart of Edinburgh. There were twenty-one honorary members and ninety corresponding members, forty-eight of them in the scientific classes. More than half the entire number was German. Up to this time the academy had given more attention to reports of what had been done by others than to original research and the diffusion of knowledge. In scientific work it was at least a generation behind the academies of England, France and Sweden. All this was now changed. Under the new order each secretary became in a

measure responsible for the work of his class, the nature and amount of which he determined. In addition to presiding at the meetings of his own class, each secretary in turn presided for a period of three months at the general meetings of the academy. Treatises receiving the prize were regarded as the property of the academy and those deemed worthy of favorable mention could be printed by it if it desired. But no paper could be printed except by a two thirds' vote of the whole academy. Out of the income of $7,000, the sum of $650 was set aside for emergencies and $700 for scientific purposes. Though cramped for means the academy was now better organized than ever. It had proved its right to live. In fact it had made a place for itself among the learned societies of the world. It had gained the respect and confidence of German scholars and was beginning to enjoy, as it had done in the time of Frederick the Great, the favor of the reigning sovereign and of his ministers of state. How this had gradually been done will be seen in a brief account of the work accomplished during the period under review.

This consisted to a very large extent in offering prizes and in deciding upon the merits of the treatises which these offers secured. The subjects discussed indicate the thought of the period. But the academy did more than read learned papers and determine their respective merits. In the sentiment it created, and by means of the topics it selected for consideration, it directed the thought of the time. Some of these topics may here be given. In 1786–87 the question to be answered was 'shall the mythology of the Greeks and the Romans be retained in modern poems, or that oldest German and northern doctrine of the gods, or the miracles of the Christian religion?' Such a question indicates unrest and dissatisfaction in the minds of some of the older poets of the time. Four years later Gedike asked the academy, 'what reason is there in the present condition of learning to look upon the ancient languages as the foundation of a liberal education, and would it be advantageous or disadvantageous for science to treat them no longer as a part of official instruction, but confine their study to a limited class of scholars?' Teachers, it was agreed by all, must learn them, but there were many, then as now, who doubted the value for all classes of pupils of training in the classical languages.

The king desired the discussion of what he was pleased to term more practical questions. For example: 'Was Brandenburg before the thirty years war better off or more populous than about 1740?' 'What was the influence of authors in the time of Louis XIV. upon the spirit and culture of the European nations?' The academy, however neutral it might desire to be, could not prevent its members from discussing the philosophy of Kant. Anxious as it was to be impartial, as a matter of fact not many of its members accepted the principles of Kant. They

treated them as the suggestions of a very able man indeed, but as suggestions in which men of sound mind would soon lose their interest.

In 1800, in order to meet and oppose romanticism, the theme discussed was 'Goths and Gothism.' A question which had been propounded several times without eliciting a satisfactory answer related to the advance in German metaphysics since the time of Leibniz and Wulff. The prize for the discussion of the theme which this question presented was finally divided between three men, Schwab of Stuttgart, receiving one half, Albricht of Erlangen one fourth, and another fourth going to Reinhold, the parish minister in Kiel. Although Kant wrote on this theme as early as 1791, for some reason he did not send in his paper to the academy, though some of his thoughts upon it were published by Rinkin in 1804. In one of his incomplete essays he defines metaphysics as 'the science of advancing from the knowledge acquired through the senses, by means of reason, to the supersensuous.' Such questions were also considered as 'What is the origin of all our knowledge?' 'Is there an immediate inner perception?' 'What is the relation of the faculty of the imagination to that of feeling?' 'What was the influence of Descartes upon Spinoza?' In 1796 a military man living in Kopenick left 10,000 thalers ($7,500), the interest to be given as a prize once in four years for the best treatment of some theme in speculative philosophy. In 1805 this prize was won by Franke for a treatise on analytic methods in philosophy.

Interesting themes in philology were also suggested. A prize was offered in 1794 for a satisfactory comparison of the chief languages of Europe, living or dead, in reference to wealth, regularity, strength, harmony or other advantages, the successful essay to show in what respect one language is superior to another, and which language, then existing or having existed, comes nearest perfection. The prize was won by Jenisch, a clergyman preaching in Berlin. There was great interest in the jubilee prize of 1800 which was won by Gebhard, another Berlin preacher, who sought to trace and estimate the influence which Frederick the Great had exerted on the spirit of his age, in reference to progress and freedom. In 1804 the academy asked, 'Why civilization has always proceeded from the east and has never developed originally in the west?'

The fact that no one of the treatises on ten different themes in mathematics, physics and astronomy was accounted worthy of a prize seems to show that these branches of study were not pursued in Germany to such an extent or with such thoroughness as in other European countries. The backward state of chemistry is indicated by the question for an essay, 'Has it been sufficiently demonstrated that there are only five species of elementary earths? Can these elements be transmuted into one another? If so, how is it done?' Practical matters, relating

to roads, crops, agriculture, also received attention. In 1782 Cothenius left 1,000 thalers ($750), the income of which was to be used every alternate year for a prize on some economic, agricultural or horticultural topic.

It was in an era of empiricism in philosophy, or with some enlightened thinkers, of eclecticism, in a time when the influence of romanticism was showing itself in such men as Nicolai, the originator of *Die allgemeine deutschen Bibliothek*, and in an extensively circulated Berlin monthly magazine, that Kant's critiques appeared. Empiricism quailed before them. The eclectics were startled. The academy was compelled to recognize the appearance of a new and a great thinker. Some of the more eminent philosophers in the academy, like Merian, Ancillon and Selle, brought forward what they regarded as weighty objections to Kant's positions. A few, far from sympathizing with Kant, did not fail to perceive his power and hesitated to enter the field against him, while others, like Nicolai and his friends, were hostile and ready to fight from the first. The majority in the academy distrusted the *a priori* and the *practical* reason upon which Kant laid such stress. But in spite of the determination of the philosophical element in the academy to defend empiricism, a change in feeling toward it began to show itself as early as 1800. This change was due, certainly in part, to the mental attitude of those classes in the academy which devoted thought and time to other subjects than those that were metaphysical. Such men as Hufeland, Dr. Walter,

the jurist, von Klein, the statesman, director Borgstede, friends of Goethe and influenced to some extent by his spirit, as well as men like Thaer, Tralles and Johannes von Müller could not fail to be dissatisfied with the empiricism of the day, and to demand a fair hearing for any system of thought which aimed at replacing it.

The scientific regeneration of Germany followed its moral regeneration. As Harnack points out, two great streams of thought were united in nearly the same men, Fichte, Schleiermacher, F. A. Wulff, Niebuhr, von Stein and William von Humboldt. Foremost among them all

ALEXANDER VON HUMBOLDT.

was Schleiermacher, preacher, professor, philosopher. The spiritual life of the eighteenth century had been determined by its study of history and its devotion to reason. It had demanded clearness, immense learning, elegance in expression, the classicism of Cicero rather than that of Greece. French influence was everywhere felt. German authors were weakened by subserviency to forms of expression and methods of thinking suggestive of the narrowness of the schools in which they had been trained. Although Hume had little influence in Germany, the writings of Rousseau were very effective in shattering the old faith. If we also take into account the writings of Winckelmann on Grecian art,

those of Herder, Kant, Wulff, Goethe, Schiller, William von Humboldt, to say nothing of scientific treatises which were constantly appearing and indicating the discovery of new fields of knowledge to be explored, it is easy to see that nothing could prevent the incoming of an era in which the largest liberty of thought and entire freedom in investigation would be demanded for every branch of study. If at first the academy

WILHELM VON HUMBOLDT.

was somewhat conservative, it soon became a regulative force in the discoveries to which its members devoted themselves with untiring enthusiasm.

Herder's 'Philosophy of History,' a remarkable work, exerted great influence on German thought as did Wulff's writings on Homer and especially his 'Science of Antiquity.' Schleiermacher's 'Reden' or addresses to the German nobility and the educated classes of the country produced a wonderful moral and religious effect. Niebuhr imparted a new spirit to the study of history through the publication of his 'Roman History,' raising it at once to the rank of a science. Schleiermacher, recognized in the academy as the clearest thinker in its membership, impressed himself on wide circles by his translation and study of Plato, his improvement of Kant and his powerful sermons in Trinity

Church, of which he was pastor, while at the same time a professor in the university. By many he is thought to be second to no philosopher in Germany save Leibniz. As an interpreter of others' thought and in his ability to present it in new forms he had no rival. Through him Spinoza and Plato spoke directly to German scholars. But all his power was exerted in ethical and spiritual directions. Patriotic to the last degree, a lover of beauty in art and literature, deeply interested in the advancement of science, he was easily the most prominent man in Berlin, and though his energies were exercised in many fields he did not fail to direct the thought and determine the activity of the period

JOHANN GOTTLIEB FICHTE.

in which he lived. By his side and that of the noble group of men just named, should be placed Savigny, student and interpreter of law, who with Kant, Fichte and Schleiermacher introduced a new ethic into German life and gave a new character to the nineteenth century.

But this development, important and valuable as it was, was not altogether friendly to the development of purely scientific studies. The academy was chiefly interested in historical and literary, esthetic and ethical studies. At the same time it was not hostile to science. Only that did not have the first place in its thought. Nevertheless,

during the period from 1786 to 1812 it numbered thirty-two mathematicians and naturalists among its members. Gerhard, mineralogist and chemist; the elder Walter, the anatomist; Achard, the chemist, were of Frederick the Great's time. Ferber, though in the academy only a short period, was the founder of modern geognosy. Some of these men did a great deal to increase the usefulness and fame of the academy. Yet there was no mathematician in its ranks equal to Euler or Lagrange. Willdenow, nephew of Gleditsch, in charge of the botanic garden, though dying at the early age of forty-seven, carried out and improved his uncle's plans. Bursdorf laid the foundations of the science of forestry, from which Germany has received such rich returns. Though Prussia was far behind in her knowledge of chemistry, Klaproth, through the academy, did a great deal for the science by introducing correct opinions in regard to its nature and by improving the methods of its study. As an independent analytical chemist he proved to be one of the most famous chemists of his time, inferior only to Berzelius of Sweden. He discovered four new elements. Alexander von Humboldt, traveler and scientist, an author of world-wide fame, Leopold von Buch, the first geognosist of the century, and hardly less famous than Humboldt, and Buttmann, the grammarian, belong to that group of scholars, thinkers, investigators and writers who laid the foundations upon which the fame of German scholarship in the last century largely rests. The change which had taken place in the spirit and aims of the academy within the period under review, typical as it was of the change which had taken place in the universities and in the nation, was that of a generation. A new era had dawned, an era which was ready to extend a hearty welcome to new men, new methods of study and research, a new life, a new and more accurate scholarship.

THE PROGRESS OF SCIENCE.

AGRICULTURAL WORK IN THE PHILIPPINES.

The introduction of American methods for the promotion of agriculture in the island possessions has followed closely upon American occupation. In Hawaii and Porto Rico experiment stations have been established under government support, and in the Philippine Islands a bureau of agriculture was put in operation about two years ago. The activity of this bureau in organizing its work of propaganda and investigation, as indicated by Professor F. Lamson-Scribner's second annual report, has been mainly along the lines of establishing experiment stations and farms, studying the conditions surrounding the principal agricultural industries, the introduction of farm machinery and improved methods of culture, and the testing and distribution of introduced plants and seed.

Seven experiment stations and farms have been established for special branches of agriculture or in typical sections of the country. These include a rice farm, a live stock farm, a sugar station, a farm for cocoanut and abacá (Manila hemp) culture, a testing station near Manila, and two other stations for general work in typical localities. For the coffee industry, formerly an extensive one in Batangas Province but now practically abandoned, owing to the ravages of leaf blight and borers, a coffee plantation has been started with imported hybrids, and it is hoped to secure resistance to disease and insect injuries by vigorous-growing varieties and thorough cultivation.

Special effort is being made to promote the rice industry, for although rice is the staple article of food for the Filipinos, not enough is produced for home consumption. The most approved American methods are being followed on the rice farm, and the crop of last year, which occupied about 1,000 acres, was seeded, cut and thrashed out with the latest machinery. This demonstration was a revelation to the natives whose methods of growing and handling the product are very primitive, and they were willing to pay a good toll for having their rice thrashed out by machinery, in preference to hand thrashing. In fact, the natives have taken readily to the modern agricultural implements and machinery introduced by the bureau, and soon get to use them skilfully.

On the hemp and cocoanut farm the problems of managing the plantations and of preparing copra, a staple article of export, are being taken up. A more careful selection of the species of abacá and better methods of culture would greatly increase the yield of merchantable fiber, and the perfection of a machine for stripping and cleaning the hemp fiber would aid greatly in developing this important industry. A very interesting study of the present methods of preparing the hemp, and its effect upon quality, is incorporated in the report.

The live stock found in the islands is for the most part of an inferior quality, and the industry is at present at a low ebb, disease (surra and rinderpest) having carried off so many of the work animals as to cripple very seriously the native farming. Improved stock of different kinds has been imported for the stock farm, and the attempt will be made to ascertain the breeds and crosses best adapted to existing conditions, and to solve the forage problem. The latter is an acute

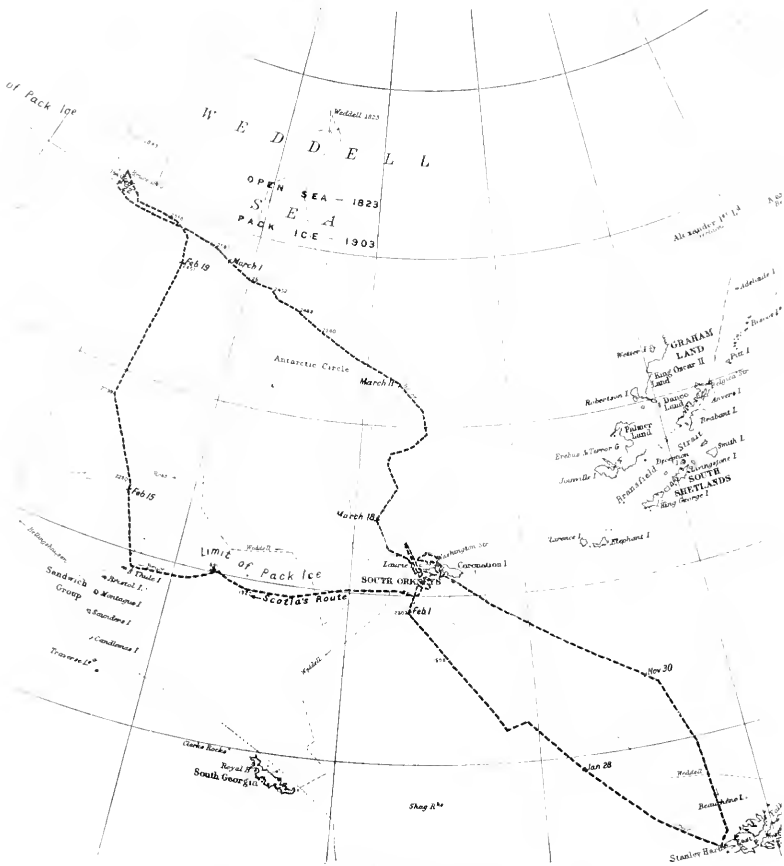
one, under present conditions, the universal forage consisting of grass cut fresh every day and sold to supply the need from day to day. Among the forage plants tested by the bureau, teosinte has given great promise, yielding enormous crops of green fodder and giving many cuttings. Nowhere in the Philippines is any attempt made to produce hay, although this is thought to be entirely practicable.

These are only a few of the more prominent lines which the bureau has already entered upon, in addition to its explorations and the publication of technical and popular bulletins, frequently in both English and Spanish. While its work has of necessity been quite largely preliminary thus far, it has clearly indicated the great opportunities which are open to it, and the value which it may be in improving and developing the underlying industry of the archipelago.

ANTARCTIC EXPLORATION.

The safe return of the British Antarctic expedition is announced by cable from New Zealand. It appears that the relief ships sent by the British government, the *Morning* and the *Terranova*, which left Hobart on December 5, reached the *Discovery* on January 5. The ice began to break at the end of the month, assisted by systematic dynamiting. On February 12 a general break-up brought the relief ships to Hut Point, and on February 14 two heavy charges of dynamite placed the *Discovery* in open water. In the succeeding days the heavy gales drove the vessels apart and the *Discovery* was driven ashore, where she remained for eight hours in a critical position before she freed herself. During the antarctic summer Captain Scott and his party made two excursions westward over a glacier. They gained the summit on October 11 and crossed the magnetic meridian on October 20 in longitude 155½ east. Proceeding still westward, the party reached a point 270 miles from the ship in latitude 78, south longitude 146½ east. The interior of South Victoria is evidently a vast continental plateau stretching continuously upward for 9,000 feet. In November another party reached a point 160 geographical miles southeast of the

THE SCOTIA IN SCOTIA BAY.



ROUTE OF THE SCOTTISH ANTARCTIC EXPEDITION.

ship. There was no trace of land, and evidence was obtained showing that this was a vast floating ice plain.

The return of Captain Scott must be awaited for accurate accounts of the scientific work of the expedition. In the meanwhile, however, reports are being published of the results of the German, Swedish and Scottish expeditions. It will be remembered that the *Gauss*, under Professor E. von Drygalski, has returned from the exploration of Wilkes Land and the Weddell Sea, while the *Scotia*, under Mr. W. S. Bruce, and the *Antarctic*, under Dr. Otto Nordenskjöld, have been in the South Atlantic. The *Antarctic* was crushed in the ice and abandoned, but the members of the expedition and a large part of the collections were rescued by the Argentine relief ship. A full account of the work of the expedition will be found in *The Geographical Journal* for February. In the *Scottish Geographical Magazine* for the same month is an account by Mr. Bruce of the voyage of the *Scotia*, and we reproduce here an outline of the route and the position of the vessel in its winter quarters in Scotia Bay on Laurie Island. Mr. Nussman and a party of five men remain at this station engaged particularly with meteorological and magnetic observations, and the *Scotia*, with the assistance of the Argentine government, is about to return.

THE SCIENTIFIC WORK OF PROFESSOR ARRHENIUS.

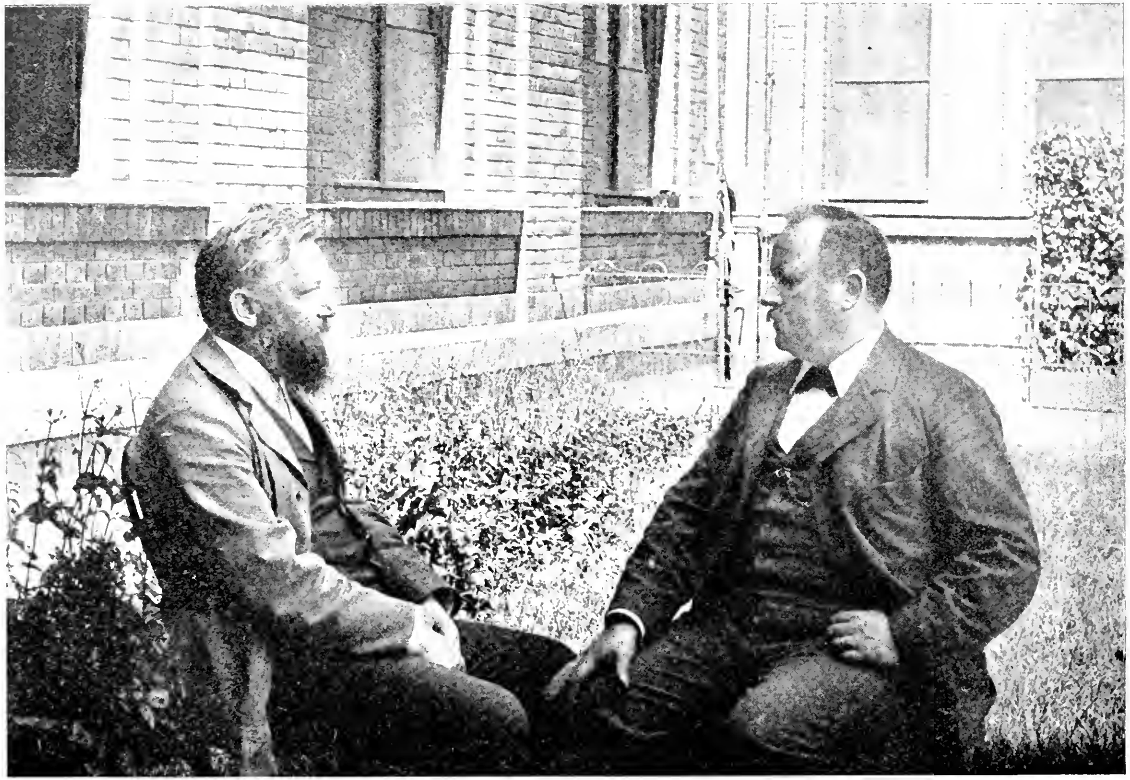
There are many people who believe that the scientific man of to-day must be a narrow specialist if he is to make a name for himself. It may, therefore, be well to consider how far this is true of Arrhenius, to whom a Nobel prize has recently been awarded. Svante August Arrhenius was born in Sweden, February 19, 1859. In 1883 he received the doctor's degree from the University of Upsala, though not in a very satisfactory way. Arrhenius had taken for his thesis the galvanic conductivity of electrolytes, and had developed the outlines of what is now known as the electrolytic dissociation theory. The importance of the work submitted by the young Arrhenius was not perceived as clearly in Upsala then as it is now. The physicists maintained that the thesis was essentially chemical in nature and that it did not represent work in the field of physics. The chemists were equally positive that the thesis dealt more with physics than with chemistry. When this latter contention was over-ruled officially, Arrhenius was given his degree 'non sine laude.'

It is probable that the thesis would have been approved with even less enthusiasm if it had not been for Professor Pettersson, who took a strong stand in favor of Arrhenius, and yet it is not much of an exaggeration to say that the Nobel prize was awarded to Arrhenius for the ideas contained in his doctor thesis. When the theory of electrolytic dissociation was supplemented by the van't Hoff theory of osmotic pressure, the aggressive energy and wonderful teaching ability of Ostwald developed physical chemistry from an unimportant and almost unrecognized subject to its present position.

In 1886 Arrhenius received a grant from the Swedish Academy which enabled him to work in Germany with Kohlrausch, in Austria with Boltzmann, in Russia with Ostwald, and in Holland with van't Hoff. His friends, however, were not able to get him any official place until 1891, when Arrhenius was given a teaching position in physics at the Stockholm Högskola. The opposition to Arrhenius was so strong that it was with difficulty that he was promoted to the chair of physics at Stockholm in 1895, and he was only elected a member of the Swedish Academy in 1901.

During the first eight years after graduation, the work of Arrhenius was chiefly chemical. The electrolytic dissociation theory was not received enthusiastically by the majority of the physicists, and the chemists, with a few striking exceptions, were even more hostile to it. The bulk of the missionary work was done by Ostwald, but Arrhenius was not backward in the fray. While never deserting the old love, new interests arose when Arrhenius was appointed to teach physics at Stockholm. We have first a series of investigations on conductivity in flames and hot gases, which is a very natural development of the earlier work on the conductivity of solutions. This work on gases led by easy transitions to a study of cosmical physics. In 1894 Arrhenius considers the effect of the moon on the electrical state of the earth's atmosphere. In 1895 a calculation of Langley's measurements on the radiation from the moon leads to a theory of the glacial period and the Eocene period as brought about by the variation in the amount of carbonic acid in the air. In 1900 we have a cosmical speculation in which there is a systematic discussion of the nature of comets, nebulæ, protuberances, faculæ and zodiacal light, as well as of the variations of barometric pressure, terrestrial magnetism, etc.

In 1903 appeared the 'Lehrbuch der cosmischen Physik,' two large volumes of approximately five hundred pages each. The first volume deals with astronomical and geological phenomena, while the second is practically a treatise on meteorology. Arrhenius takes



OSTWALD ARRHENIUS.

a decided stand in regard to the question of solar heat. He rejects the theories of Helmholtz and Kelvin, as being incompatible with geological evidence. While chemical theories have been considered hopelessly insufficient to account for the tremendous outpour of heat observed, Arrhenius advocates a return to them. He points out that the exchanges of energy in the redistribution of chemical equilibria are enormously greater at very high temperatures than at lower ones and that for this reason computations made from laboratory data have no bearing on the problem. While this hypothesis of Arrhenius may not stand the test of time, it is an interesting one and especially in view of the peculiar heat effects manifested by radium. Of the book itself Professor Barus says, in a review: "As a whole the work will take rank beside the great contributions of Mohn, Guldberg (who, it will be noted, shared with Arrhenius this double allegiance to chemistry and geophysics), and others, who have made meteorology a debtor to the thinkers of the North." It may also be mentioned that Arrhenius will attend the International Congress of Arts and Science at St. Louis as one of the speakers before the Section of the Sciences of the Earth.

The most recent papers of Arrhenius deal with the chemistry of serums, and it seems probable that the study of medical problems will occupy much of his time during the next few years. In Arrhenius we have a man who has received the Nobel prize before he was forty-five, and whose scientific work ranges from salt solutions to comets and from glacial periods to the typhoid bacillus. Such a record lends little support to the belief that a scientific man must be a narrow specialist if he is to attain eminence. This belief rests on a misapprehension. It is true that scientific men are accumulating facts at a tremendous rate and that this apparently makes it more and more difficult for any one man to be master of anything more than a small branch of a single science. Along with this accumulation of isolated facts, however, there comes the development of great simplifying generalizations or laws which enable men to grasp and remember an enormous number of facts. It is only during the brief periods when the discovery of new facts has not yet given rise to newer and more comprehensive theories that there is even an appearance of narrowness.

LINNÆUS.

Carolus Linnæus was born on May 13, 1707, and suggestions have already been made as to the celebration of the bicentenary of his birth. The centenary of his death was duly commemorated by the erection of a statue in Stockholm by Professor Kjelberg which stands in the Humlegarden, and represents the great naturalist holding in his hand the 'Systema Naturæ' and surrounded by allegorical figures representing botany, zoology, mineralogy and medicine. Just what form the celebration of the bicentenary of Linnæus's birth will take in his native country has not been decided, but it is not perhaps too early to make preparations for a suitable commemoration in America.

There has perhaps been in recent years a tendency to depreciate the work of Linnæus, some of his ideas having been discovered in the publications of previous writers and his works naturally containing many mistakes. But he is the founder of botany and in a way of modern natural history to an extent but rarely vouchsafed in science to a single man. He left order where there had been confusion, and largely prescribed the development of a science for a century, until the time of Darwin and the theory of evolution. Linnæus himself seems almost to have foreseen the course of events, for he said: 'A natural method is the first and last thing to be desired in botany; nature does not make leaps.'

Carolus Linnæus.

The education of Linnæus was irregular, as has been frequently the case with men of science, and his early life was more adventurous than is usual at the present day. His interest in the names and qualities of plants is said to have begun at the age of four. His father, who was a clergyman, wished to train him for the church, but when he showed no taste for routine studies, he was almost apprenticed to a shoemaker. He made his way through Swedish universities with many adventures and spent a number of years in Holland, whence he visited England. He practised medicine for a time at Stockholm, but finally received a professorship at Upsala which he held for thirty-seven years. He made this northern town the center for natural history in Europe, its students increasing from 500 to 1,500 through his influence. Expeditions proceeded thence to all parts of the world, and all discoveries were reported to Linnæus, resulting in a large series of works by him and his pupils. All honors were then showered upon him. He was ennobled under the name Carl von Linné and founded an estate. His son inherited his position at the university, but not his talents. When he died on January 10, 1778, his reputation was world-wide, and his name will always be a landmark in the history of science.

PRESIDENT ELIOT.

The seventieth birthday of President Eliot, perhaps the greatest American now living, was celebrated at Harvard University on March 20. Mr. John Sargent has been invited to paint a portrait which will be placed in the Harvard Union. The following admirably expressed letter with some ten thousand signatures was presented to President Eliot:

March 20, 1904.

Dear Mr. President: As with undiminished power you pass the age of seventy, we greet you.

Thirty-five years ago you were called to be president of Harvard College. At the age of thirty-five you became the head of an institution whose history was long, whose traditions were firm, and whose leading counselors were of twice your age. With prophetic insight you anticipated the movements of thought and life; your face was towards the coming day. In your imagination the college was already the university.

You have upheld the old studies and uplifted the new. You have given a new definition to a liberal education. The university has become the expression of the highest intellectual forces of the present as well as of the past.

You have held from the first that teacher and student alike grow strong through freedom. Working eagerly with you and for you are men whose beliefs, whether in education or in religion, differ widely from your own, yet who know that in speaking out their beliefs they are not more loyal to themselves than to you. By your faith in a young man's use of intellectual and spiritual freedom you have given new dignity to the life of the college student.

The universities and colleges throughout the land, though some are slow to accept your principles and adopt your methods, all feel your power and recognize with gratitude your stimulating influence and your leadership.

Through you the American people have begun to see that a university is not a cloister for the recluse, but an expression of all that is best in the nation's thought and character. From Harvard University men go into every part of our national life. To Harvard University come from the common schools, through paths that have been broadened by your work, the youth who have the capacity and the will to profit by her teaching. Your influence is felt in the councils of the teachers and in the education of the youngest child.

As a son of New England you have sustained the traditions of her patriots and scholars. By precept and example you have taught that the first duty of

every citizen is to his country. In public life you have been independent and outspoken; in private life you have stood for simplicity. In the great and bewildering conflict of economic and social questions you have with clear head and firm voice spoken for the fundamental principles of democracy and the liberties of the people.

More precious to the sons of Harvard than your service as educator or citizen is your character. Your outward reserve has concealed a heart more tender than you have trusted yourself to reveal. Defeat of your cherished plans has disclosed your patience and magnanimity and your willingness to bide your time.

Fearless, just, and wise, of deep and simple faith, serene in affliction, self-restrained in success, unsuspected by any man of self interest, you command the admiration of all men and the gratitude and loyalty of the sons of Harvard.

THE WILL OF HERBERT SPENCER.

Mr. Spencer's will is a document so interesting and characteristic that we quote some of the details, as published in the London *Times*. The first clause gives very exact directions as to the burial, and the executors are not to receive their fees unless these are observed. The clause reads: "I direct that if I shall die in any part of Great Britain, my body shall be placed in a coffin with a loose lid easily opened from below, and that it shall be subsequently burned in a proper crematory, and the ashes taken to the space numbered 33,292 purchased by me in the unconsecrated part of the Highgate Cemetery, and deposited in a fit cavity made in the concrete foundation underlying the stone slab now placed there; and my express direction is that my cremation and the subsequent deposition of my ashes shall be conducted without any species of religious ceremony such as is used either by the Church of England or any other sect, though I do not object to an address delivered by a friend; but otherwise the ceremony is to be silent, and I direct that no monument shall be placed over my ashes until at least two months after my funeral."

Among the books and manuscripts bequeathed to the trustees and executors are the 'Autobiography' with directions to secure its simultaneous publication in England and America after the corrections have been made that are marked in the press copy. The 'Autobiography' will be published in America by Messrs. D. Appleton and Co. at about the same time as this issue of the Monthly. Mr. David Duncan is requested to 'write a biography in one volume, of moderate size, in which shall be incorporated such biographical materials as I have thought it best not to use myself together with such selected correspondence and such unpublished papers as may seem of value, and shall include the frontispiece portrait and the profile portraits, and shall add to it a brief account of the part of my life which has passed since the date at which the autobiography concludes.' The trustees are to give their approval of the biography before it is published, and to arrange with the biographer 'for payment either of a fixed sum to be paid out of my estate or by receipt of the net proceeds of sales in England and the United States; but if the net receipts exceed £600, then the surplus to be equally divided between the biographer and my trustees, who will retain the copyright.'

The will makes numerous personal bequests, such as to Dr. Henry C. Bastian—telescope, case of drawing instruments, etc., reading easel, 'and the invalid bed of my invention with its appliances for private or public use'; to Mrs. Leonard Courtney—a victoria with india-rubber tires; to Mrs. Sidney Webb—'the piano given to me by my American friend, Mr. Andrew Carnegie,' with music-stool, music-shelves, and contained music.

The income from invested property

and from the sale of his works is to be used for the completion of the 'Descriptive Sociology.' "I declare that my trustees shall apply as nearly as possible the whole of the income derived from all investments for the time being representing my residuary estate and also the income derived by my estate from the publication and sale of the works mentioned in this my will (including the autobiography and biography) in resuming and continuing during such period as may be needed for fulfilling my express wishes, but not exceeding the lifetime of all the descendants of Queen Victoria who shall be living at my decease and of the survivors and survivor of them, and for twenty-one years after the death of such survivor, the publication of the existing parts of my 'Descriptive Sociology' and the compilation and publication of fresh parts thereof upon the plan followed in the parts already published. And I expressly empower my trustees to delegate to some competent person the duty of selecting and appointing (subject to their approval) competent compilers, deciding (subject to their approval) upon successive works to be undertaken by them, overseeing the execution of such works, superintending their approval) upon the remuneration of such compilers, and rendering periodical reports and accounts to my trustees, and out of such annual income my trustees shall appropriate and pay to the person so delegated £150 per annum, or such larger sum as, having regard to the work done, they may think reasonable and proper. And I wish that the first person so appointed shall be Henry Tedder, secretary and librarian to the Athenæum Club."

The ultimate disposition of the estate is as follows: "When the series of works, and the reorganized work, specified above shall have been completely executed and published, my trustees shall thereupon sell by auction the copyrights, stereotype plates and stock of the whole body of them, and shall sell in like manner the copyrights, stereotype plates and stock of such of my works, if any, as continue to be published by them, and shall sell in the usual way the shares, stocks, funds, securities and other property held by them as trustees, and shall give the sum realized in equal parts to the Geological Society, the Geographical Society, the Linnean Society, the Anthropological Institute, the Zoological Society, the Entomological Society, the Astronomical Society, the Mathematical Society, the Physical Society, the Chemical Society, the Royal Institution and the British Association, or such of them as shall then be in existence, and shall accept the gift upon the condition in each case that the sum received shall, within five years from the date of payment, be spent by the governing body for the purchase or enlargement of premises, or for books or apparatus, or collections, or for furniture or repairs, or for equipment, or for travelers and donations of instruments of research; but in no way or degree for purposes of endowment; and, after having previously made an authorized statement of the purposes for which the donation is to be used, the receipt or acknowledgment by the treasurer or secretary of the society to or for the benefit of which the payment is made to be in each case an absolute discharge to my trustees, and a certificate in writing signed by all my trustees stating that they have carried out the provisions of the trust to the best of their judgment and ability shall be a complete termination of their responsibilities and shall be conclusive and binding on all persons and institutions interested under this my will."

SCIENTIFIC ITEMS.

We regret to record the death of M. F. A. Fouqué, the well-known French geologist and mineralogist; of Dr. Karl Schumann, titular professor of botany at Berlin and curator of the Royal Botanical Museum; of Henri Perrotin,

director of the Observatory at Nice; of Dr. W. W. Markownikow, professor of chemistry in the University of Moscow; of Arthur Greeley, professor of biology at Washington University, St. Louis; and of John I. Jegi, professor of psychology and physiology in the Milwaukee State Normal School.

Dr. Alexander Agassiz, director of the Harvard University Museum and president of the National Academy of Sciences, has been advanced to a foreign associate of the Paris Academy of Sciences, to fill the vacancy caused by the death of Sir George Gabriel Stokes.—McGill University has conferred the degree of LL.D. on Dr. Edward L. Trudeau of Saranac Lake, N. Y., in recognition of his work on the open-air treatment of tuberculosis, and on Mr. Edward Weston, of Newark, N. J., the investigator and inventor in electrical science.—Dr. Simon Flexner, director of the Rockefeller Institute, New York, has been elected president of the American Association of Pathologists and Bacteriologists.

Professor C. S. Sherrington, of Liverpool University, opened his course of Silliman lectures at Yale University on April 22.—The subjects of the Herter lectures given during April at the Johns Hopkins University by Professor Paul Ehrlich were: (1) 'The mutual relations between toxine and antitoxine'; (2) 'Physical chemistry versus biology in the doctrines of immunity'; (3) 'Cytotoxines and cytotoxic immunity.'

The new medical laboratories of the University of Pennsylvania will be dedicated on June 11. The laboratories cost $700,000. The principal addresses will be delivered by Dr. H. P. Bowditch, professor of physiology at the Harvard Medical School; Dr. R. H. Chittenden, director of the Sheffield Scientific School, Yale University; Dr. George Dock, professor of medicine at the University of Michigan, and Dr. Horatio C. Wood, professor of materia medica and pharmacy at the University of Pennsylvania.—Active preparations are being made at the New York Zoological Garden in Bronx Park for taking the animals out of winter quarters. Work is also being pushed with all possible speed on several new houses in the garden, the most important of which are the bird house, to cost $115,000; the small mammal house, to cost $38,000, and the ostrich house, to cost about the same sum.—The executive committee of the Carnegie Institution has adopted the recommendation of the biological committee to establish a Department of Experimental Biology and to call Professor C. B. Davenport, of the University of Chicago, to the charge of it. The work of the department will include at present, among others, a station for Experimental Evolution at Cold Spring Harbor, Long Island, on land granted by the Wawepex Society, and a Tropical Marine Biological Station at the Dry Tortugas. Dr. Davenport is proposed as director of the former station and Dr. Alfred G. Mayer, of the Museum of the Brooklyn Institute of Arts and Sciences, as director of the latter station. Fuller details are promised as the plans of the department progress.

THE
POPULAR SCIENCE
MONTHLY.

JUNE, 1904.

THE TOTAL SOLAR ECLIPSE OF AUGUST 30, 1905.

By Professor W. W. CAMPBELL,
DIRECTOR OF THE LICK OBSERVATORY, UNIVERSITY OF CALIFORNIA.

THE last total eclipse of the sun observed was that of May 17, 1901, whose path crossed the islands of Mauritius, Sumatra, Borneo and New Guinea. Its durations, in Sumatra six and a half minutes, was the greatest of any observable eclipse of the last half century. The shadow touched the islands at very few accessible points, and the choice of observing stations was unusually limited. Nevertheless, observations were undertaken by a relatively large number of well-equipped expeditions from this country and Europe. At nearly all stations clouds of various degrees of thickness covered the eclipsed sun, and the work was seriously hampered by them. Fortunately, many valuable photographs were secured through thin clouds. For example, Professor Perrine, in charge of the William H. Crocker Expedition from the Lick Observatory, obtained results of great value with each of his ten instruments, though only five to twenty-five per cent. of the light passed through the clouds. In fact, it would be difficult to say wherein they could have been better, except that the intra-mercurial planet search was incomplete in one third of the area called for in the program.

A total eclipse, of short duration, occurred on September 20, 1903, in the southern Indian Ocean. The shadow did not pass over land, unless within the closed south polar continent, and no effort was made to secure observations.

A long eclipse will occur on September 9, 1904. It, too, will come and go practically unobserved, for its path passes eastward over the central Pacific Ocean without touching any known islands, and terminates on the coast of northern Chile about six minutes before sunset.

With the sun at such a low altitude, the atmospheric disturbances and the almost complete absorption of actinic rays will preclude the possibility of securing satisfactory observations, except perhaps as to the general form of the corona. It is known that the Chilean astronomers are expecting to view the phenomenon. Further plans do not seem to be called for.

The next observable eclipse is that of August 30, 1905. It is well situated, and will be looked forward to with unusual interest. The shadow path begins at sunrise south of Hudson's Bay, enters the Atlantic Ocean a short distance north of Newfoundland, crosses northeastern Spain, northeastern Algiers and northern Tunis, passes centrally over Assuan on the Nile, and ends at sunset in southeastern Arabia. The durations on the coast of Labrador, in Spain and at Assuan, are two and a half, three and three fourths and two and three fifths minutes, respectively.

It is none too soon to form plans for observing this eclipse. In this connection, an account of the leading eclipse problems now pressing for solution may have interest for the general reader, and perhaps some usefulness to those who will plan programs of work, though the latter will prefer a more detailed article than would be justified here.

There is probably no phenomenon of nature more beautiful and impressive than a total eclipse of the sun. Every such event is of great human interest. Even the uncivilized tribes of the earth realize, crudely, the force of the scientific fact that the sun is the origin of the light, heat and other forms of energy which make life on this planet possible.

The absorbing interest taken in eclipses by astronomers is on a broader basis. Our sun is one of the ordinary stars. In size it is perhaps only an average star; or it may even be below the average. It is the only star near enough to us to show a disk. All other stars are as mathematical points, even when our greatest telescopes magnify them 3,000-fold. The point-image of a distant star includes all its details, and it must be studied as a whole, whereas the sun can be studied in geometrical detail. Our sun is likewise the only star bright enough to supply metrical standards demanded in the study of other stars. It is not too much to say that our physical knowledge of the stars would to-day be practically a blank if we had been unable to approach them through the study of our sun. If we would understand the other stars, we must first make a complete study of our own star. Several of the most interesting portions of our sun are invisible, except at times of solar eclipse. Our knowledge of the sun will be incomplete until these portions are thoroughly understood; and this is the reason why eclipse expeditions are despatched, at great expense of time and money, to occupy stations within the narrow shadow belts.

The difficulties of solar study, in spite of comparative nearness and intense brightness, are very great. It is not generally appreciated that we are unable to study the body of the sun except by indirect methods. The interior is invisible. The spherical body which we popularly speak of as the sun is bounded by the opaque photosphere—a cloud covering composed of condensed vapors of the metallic elements. The photospheric veil, including the larger interruptions in it which we call the sunspots; the brighter areas, closely connected with the photosphere, called the faculæ; the reversing layer, a few hundred miles in thickness, immediately overlying the photosphere; the chromosphere, a shell several thousand miles thick, associated with and overlying the reversing layer; the prominences, apparently ejected from the chromosphere; and the corona, extending outward from the sun in all directions to enormous distances; these superlatively interesting features of the sun, constituting the only portions accessible for direct observation by telescope and spectroscope, are an insignificant part of its mass. They are literally the sun's outcasts. Our knowledge of the sun is based almost entirely upon a study of these outcasts. We might hope to reach safe conclusions as to the characteristics of a hermit nation by making a careful study of its banished subjects, provided the observed types correspond with types produced by our own civilization; but if new types, new customs, new forms, presented themselves, and were observable only at long range, our conclusions as to the characteristics of the country from which they were expelled would come slowly and uncertainly. It is a difficult matter to comprehend the structure and condition of any one of the sun's outcasts; the chromosphere, for example. To determine what the conditions within the body of the sun must be in order to create and maintain such an outcast shell is far more difficult.

The influence of eclipse observations upon solar and astrophysical research has been most remarkable. The reversing layer, the chromosphere, the prominences and the corona were in fact discovered at eclipses. Many of our present every-day methods of studying them are also eclipse products. The richness of eclipse results, considering the remarkably short intervals available for observation, is unique in science. To realize this, we need only recall that the durations of observable total eclipses, clear and cloudy, have amounted altogether to about one hour since the spectroscope was applied to the problem, and about half an hour since photographic methods have prevailed.

Eclipse problems relate not only to the properties of the less massive portions of the sun—everything, apparently, outside of the photospheric layer—but to the question of possible planets between the sun and Mercury. It is well known that mathematical theory, based upon Newton's law of gravitation, has not yet fully accounted for the motion

of Mercury. The perihelion of its orbit moves forward at least 40″ in a century more than theory calls for. The most plausible way of accounting for this progression has been the supposition that an undiscovered planet, or a group of small planets, exists within the orbit of Mercury. The search for such objects has been a well-defined eclipse problem; the sun-lit sky prevents effective search by every-day methods. Organized efforts to discover such bodies by visual means were made at the eclipses of the late seventies and early eighties, but they were unsuccessful. Photographic methods, though not planned for efficiency in that particular problem, were applied in the nineties. Early in the year 1900 it occurred independently to Professor W. H. Pickering, of Harvard College Observatory, and to Messrs. Perrine and Campbell, of the Lick Observatory, that efficiency in the photographic method requires the cameras to be of relatively long focus, in order to reduce the intensity of sky illumination on the photographic plate; and each of these astronomers, unknown to the other two, fixed upon the proportions which such instruments should have. Their results were in good general accordance. The first attempt to apply this method was made by Professor Pickering at the eclipse of May, 1900, with camera lenses three inches in aperture and 135 inches in focal length, but no evidence was secured. Mr. Abbot, of the Smithsonian Institution party, obtained one photograph with a similar lens, covering a limited area of the sun's surroundings, which recorded eighth magnitude stars. Four suspicious images on the plates were noticed; but whether they were ordinary photographic defects or images of real objects could not be determined, as the required second plate of the same region was not secured by this party or others.

The last word on the subject is by Perrine, who applied the method in Sumatra in May, 1901. His four telescopes, making three exposures each, secured negatives in duplicate of a region 6° wide and 38° long—19° on each side of the sun, in the direction of the sun's equator. Through thin clouds covering two thirds of this area, one hundred and sixty-two stars, including several as faint as the ninth magnitude, were photographed; and through thicker clouds covering the remaining third, eight stars, four of them between 6.0 and 6.5 visual magnitudes, were recorded. While these instruments were in use in the preceding February at the Lick Observatory, exposures were made on the region of the sky which would be occupied by the eclipsed sun in May. All objects on the Sumatra eclipse plates were recognized as known stars, by means of the February Mount Hamilton plates.

It is probable that any such planets would be well within the region covered, provided their orbit planes make a small angle with the sun's equator. The earth was very nearly in the plane of the sun's

equator on May 18—exactly in it on June 3—which was a favorable circumstance. Again, there is little probability that such bodies would be as much as nineteen degrees from the sun, and a width of six degrees would therefore allow for a considerable departure of the orbit planes from the solar equator.

Professor Perrine has deduced the following interesting results from these observations:

Before drawing any conclusions from these observations it is desirable to determine the relative brightness and size which any bodies in this region would have, by means of other members of the solar system. The asteroids seem to be best suited for this investigation, as they probably most nearly resemble the hypothetical intramercurial planet in size and condition of surface. The determination of the diameters of the four principal asteroids by Barnard [as below] renders these bodies the most suitable for such work.

Asteroid.	Visual Magnitude.	Distance, Miles.
Ceres	7.5	485
Pallas	8.5	304
Juno	9.5	118
Vesta	6.6	243
Arithmetical mean	8.0	290

The above magnitudes are those obtained at the Harvard College Observatory by photometric means. The results show such a wide range in albedo that the simple mean has been taken to represent the relations between magnitude and diameter for the group.

Assuming that the distance of the 'mean asteroid' from the earth is 153 million miles, we find that such a body, if transported to a distance of twenty-eight million miles from the sun (corresponding to an elongation distance of eighteen degrees), and seen from the earth at elongation, would be one hundred and ten times as bright. This corresponds to an increase in brightness of 5.1 magnitudes. Such a body would be relatively brighter near superior conjunction, and fainter near inferior conjunction. An intramercurial planet at the above mean distance from the sun would have to be only one tenth the diameter of the mean asteroid to appear of the same brightness.

From the dimensions and brightness of the four brighter asteroids we find that on the average one of these bodies, three hundred miles in diameter, seen at the opposition distance of the mean asteroid, would appear as of the eighth magnitude. Hence an intramercurial planet of similar constitution and thirty miles in diameter should appear as a star of eighth magnitude. If the hypothetical planet were closer to the sun, the difference of brightness and size would of course be correspondingly greater than that found above.

These observations indicate, therefore, with the exception to be noticed later, that there is no planetary body as bright as 5.0 visual magnitudes within eighteen degrees of the sun whose orbit is not inclined more than seven and one fourth degrees to the plane of the sun's equator. They further indicate that in two thirds of this region there was no such body as bright as seven and three fourths magnitude. The possible exception to be noted is that at the time of the eclipse such a body or bodies might be directly in line with the sun or with the brightest portion of the corona. The area covered by the moon's disk and corona was, however, less than one two-hundredth that of the region

searched. Owing to the increased cloudiness at the end of totality, the search is not quite complete to the fainter magnitude, yet it seems altogether probable that were there any considerable number of bodies as bright as seven and three fourths magnitude, some of them would have been detected. A planetary body thirty-four miles in diameter would, under the conditions considered, appear as a star of seven and three fourths magnitude. The total mass required to produce the change observed in the orbit of Mercury is about one half the mass of the planet. It would require, therefore, no less than seven hundred thousand bodies thirty-four miles in diameter and as dense as Mercury to equal such a disturbing mass.

From the observations detailed above it does not seem possible that sufficient matter exists in the region close to the sun in the form of bodies of appreciable size to account for the observed perturbations.

Belief in the existence of intramercurial planets has been based upon anomalies in the orbital motion of Mercury, and Perrine's work has gone far to show that the discrepancies must seek some other explanation. Had the thicker clouds not reduced the *minimum visible* in one third the area observed in Sumatra from the ninth to the sixth magnitude, it is a question whether one could recommend that this search be continued at future eclipses. However, so long as we admit that it is a question, the effort to secure definite results, positive or negative, should be made. It is not impossible that existing bodies could have been in the region of thicker clouds, or in that occupied by the moon and inner corona, or in areas outside the limits of the strip six degrees wide.

The eclipse of August 30, 1905, will occur when the earth is seven degrees from the plane of the solar equator. The maximum distance occurs September 7. It will therefore be advisable to search over a region of considerably greater width than was the case in 1901. Inasmuch as increased area means increased instrumental equipment, expense, and difficulty, a corresponding shortening of strip to be observed would perhaps be justified. It is to be hoped that observing parties well equipped for the intramercurial search will be located in Labrador, Spain, Tunis and Egypt. If clear weather prevails at any of the four stations, very valuable results may be secured. Should a new planet be observed at three such stations, the enormous interest attaching to its discovery would be heightened by the fact that its approximate orbit could be determined at once. If no planets are revealed on first class plates, the negative result would be scarcely less valuable, though certainly less interesting, than positive results; and the intramercurial question would cease to be a pressing eclipse problem.

The sun's altitude will be only 26° in Labrador and 23° in Egypt. The altitude of the lower end of the area to be photographed will be small at these stations. The atmospheric disturbances and absorption at such low altitudes will require that the exposures be lengthened. Perhaps a better plan would be for the Labrador party to cover the

entire critical region west of the sun, and only five or six degrees below it; and for the Egyptian party to cover the whole region east of the sun and only five or six degrees below it.

Eclipse observation of the sun itself concerns all that lies outside the photosphere and faculæ. While the main features of these outer volumes are for the most part quite irregular in form, yet in a general way they lie, going outward from the photosphere, in the order of reversing layer, chromosphere, prominences and corona.

The reversing layer was discovered at the eclipse of 1870 by Professor Young. It appears to consist of a thin stratum of incandescent gases, probably between five hundred and fifteen hundred miles in thickness, immediately overlying the photosphere. Its inner bounding surface seems to be quite definite and regular, but its outer surface is certainly not so. The depth of the stratum of vapor for each element composing it is probably a function of the properties and quantity of the element in question. The reversing layer is cooler than its substrata, yet abundantly hot, if isolated from its underlying strata, to produce a spectrum consisting of thousands of bright lines occupying the positions of the dark lines of the ordinary photospheric spectrum. When the moon, at the eclipse of 1870, gradually covered the photosphere, the dark-line spectrum lasted until the instant when the photosphere entirely vanished, whereupon the reversing layer was isolated, and Young observed the sudden flashing out of its bright-line spectrum. A bright line apparently replaced each dark line, and lasted perhaps two or three seconds, until the moon entirely covered the reversing stratum.

In so complex a spectrum, lasting but a few seconds, visual observations were difficult, and no records of any considerable consequence could be made. The bright-line (flash) spectrum was photographed for the first time by Shackleton at the eclipse of 1896; and several photographs of it were secured at the three succeeding eclipses, but many were defective on account of poor focusing or other cause. They confirm Young's discovery of the reversing layer, which, by the absorption of its cooler gases, introduces the dark lines in the solar spectrum. The lengths of the arcs not covered by the moon also tell us much concerning the thicknesses of the vapors of the various elements, and therefore much concerning the structure of the sun at those levels. Additional work, with more powerful instruments, in perfect adjustment, is demanded, with a view to securing better quantitative results.

Photographs of the reversing-layer spectrum, made with two, four, or more seconds' exposure, are integrated effects. Changes taking place during the exposure are lost. For this reason, it would be very valuable if a continuous record of the spectrum at one point on the limb could be secured on a plate moving in the direction of the length

of the spectrum lines. The writer obtained such photographs in 1898 and 1900, but with small instruments, not designed especially for that work; and it is hoped that improved apparatus will be available for the eclipse of 1905. There is need that flash spectra with both fixed and moving plates should be secured, since each system has its advantages and disadvantages. On moving plates the faintest lines might not be recorded, but a continuous record of changes in the strengths of lines, as the moon gradually covers the reversing strata, should be obtained.

The chromospheric stratum, overlying the photosphere, is of irregular depth, varying from four thousand to ten thousand miles. The reversing layer, to the best of our knowledge, is included in its lower strata. The prominences seem to be flame-like or explosive projections extending outward from the chromosphere; the matter in them previously and subsequently forming a part of the chromosphere. Many of the salient facts known about chromosphere and prominences were learned at eclipses; and they are still studied with some profit on such occasions. However, the spectroscopic method of observing them, devised independently by Janssen and Lockyer in 1868, has made the prominences, and to some extent the chromosphere, available for everyday study. But it must not be overlooked that, while fairly satisfactory observations of one or both subjects can be secured without an eclipse, yet the eclipse negatives are still imperatively needed to show the mutual relations of the various structures—reversing layer, chromosphere and inner gaseous corona. It is known that the prominences are larger and more numerous at sunspot maxima than at other times. The question whether the chromospheric stratum is likewise thicker and more distorted at sunspot maxima than at minima is a question for eclipse observers to settle. Observations of the continuous spectrum of prominences or chromosphere can by present methods be made only at eclipses.

The corona, perhaps the most fascinating solar feature, is exclusively an eclipse phenomenon. Various attempts have been made to observe it visually, photographically and thermally, without an eclipse; but all failed, and there seems to be no hope of success by methods now known. Any chance for even moderate success would seem to be limited to the inner portion whose spectrum contains bright lines. A daily record of this would, no doubt, be extremely valuable, but the real problem of the corona would remain unsolved.

In many respects the corona is as enigmatical as ever. A coronal photograph is the result of a projection upon and into one plane, at right angles to the line of sight, of all that remains of the sun after subtracting the volume of matter hidden by the moon. The tops of some coronal streamers, the intermediate portions of others, the bases of those near the limb and the corresponding parts of prominences

and chromosphere are all projected into one point. Whether every man who has gone forth to solve the riddle of the corona has fully realized the odds against success is doubtful.

Much has been written concerning a possible eruptive origin, or about magnetic influences in shaping the forms of its streamers. It has been shown that the details of the corona at one eclipse are totally different from those at another, and that the outline form of the corona is a function of the sun spot cycle. At sun spot maximum the general form is nearly circular, and the polar streamers are nearly as bright as the equatorial streamers. At minimum, the polar streamers are much fainter than the equatorial ones, and long wings seem to extend out approximately from the spot zones. It is a surprising fact that, with all the changes of form, we do not yet know whether the materials composing the streamers are moving in, or out, or both, or neither. The epoch-making, large-scale coronal photographs by Schaeberle in 1893 opened a promising way of determining such facts, but astronomers have been slow in taking advantage of the opportunity. Photographs of the corona should be secured for this purpose at widely separated stations—preferably at three or more stations—with essentially identical instruments, and with equivalent exposures, in order that results may be as nearly comparable as possible. This effort to determine motion in the corona, it seems to me, is the most important problem of the coming eclipse; and, fortunately, the circumstances of widely separated stations in Labrador, Spain, Tunis and Egypt, and promising weather conditions at the last three are favorable for the attack. Considering all elements of the question, including that of probable unsteadiness of the atmosphere at one or more stations, the five-inch aperture, forty-foot focus cameras, promise the most directly comparable, and therefore the best, results. The only case of motion on coronal plates thus far observed seems to be that detected by Schaeberle, on the Chile-Brazil-Africa plates of 1893; and in this instance the moving mass was decided to be a comet, and not a part of the real solar appendage.

One of the most intensely interesting features ever observed in the corona was the tremendous funnel-shaped disturbance recorded on the Sumatra plates of 1901. Perrine was able to show, with essentially no room for doubt, that the vertex of the disturbance was immediately over the large and only sun spot visible on the sun in the week preceding and the week following the eclipse. The circumstances were unusually favorable for reaching this conclusion: there was but one sun spot; it was very near the limb at the time of the eclipse; there was but one region of unusual disturbance visible in the corona; this was on an extraordinarily large scale, and its vertex was near the sun's limb; and the disturbance and the sun spot had identically the same

position on the sun's limb. It was exceedingly unfortunate that three cameras of the forty-foot pattern could not have been working in harmony, at three stations widely separated, to determine what changes, if any, were taking place in the disturbed coronal area. Under excellent atmospheric conditions, cameras still larger than those referred to should record more minute details of coronal structure, and thus lead to valuable results; but such observations would reach their full value only in case comparisons could be instituted with photographs taken under similar conditions at distant stations. However, as already stated, cameras of the forty-foot pattern give greater promise of cooperative usefulness, taking into account the average atmospheric conditions which must be expected at some of the stations.

The spectra of recent coronas have led to most interesting results. They leave no doubt that, at those eclipses, the spectrum of the inner corona contained no perceptible dark lines. Perrine's Sumatra photographs seem to establish that the spectrum of the great outer portion is substantially a copy of the solar spectrum. The simplest interpretation of these observations is that the outer corona is largely composed of minute particles which reflect and diffract the sunlight falling upon them, whereas the portions near the hot solar surface are mostly incandescent, shining by their own light. Polarigraphic observations are in harmony with this theory. Opposed to the idea of the incandescence of the inner corona stands, alone, the thermographic observations by Abbot in 1900, of a corona less hot than the instrument with which he worked. While it is difficult to assign such a low temperature to particles near the solar surface, and one should perhaps look for other interpretations of the thermographic results, yet there is an urgent demand for a repetition of all the preceding observations bearing upon the nature of the corona.

The polarigraphic observations of recent coronas have been very interesting—leading to the knowledge that the light of the corona is strongly polarized, except, apparently, in close proximity to the sun's surface; and strengthening the view that the corona is very largely composed of minute particles of matter which receive their light from the photosphere. Unfortunately, the photographs do not permit the making of quantitative measurements of the amount of polarization in and across the solar radii; and future programs for eclipse observations in this line should make provision for securing comparable unpolarized coronal images for standards of reference.

Special interest will be taken in determining whether the comparatively shallow inner stratum of the corona which yields a bright-line spectrum, is more extensive at the sunspot maximum of 1905 than it was at the minimum of 1898–1901. The chances are that it will be both thicker and more uniform in thickness. Should it be brighter

than at recent eclipses, the opportunity to search for new coronal bright lines will be excellent.

The accurate wave-length of the principal coronal bright line, near λ 5303, should be determined. A modern spectrograph, holding three dense flint prisms, should make the problem easy. The accurate wave-lengths of all truly coronal lines should be determined as rapidly as possible, partly in order that a serious effort may be made to represent them by a simple common law, as has been done for hydrogen and helium.

Of many other eclipse problems—the photometry, the shadow bands, etc.—it need only be said that accurate observations will prove very useful.

The tendency of recent eclipse work is toward a unification of the problem. The main divisions of the sun's structure are no longer to be studied separately. Close connection has been observed between spots and faculæ; between photosphere and reversing layer; between sun spot and coronal disturbances; between coronal streamers and prominences; between prominences and chromosphere; between the sunspot curve and the form of the corona; and in other ways the unity of the problem is emphasized. This is only what we should expect, for all these outward and visible features of the sun must be related products of the stupendous forces at work within its body. In reality, all observations of the sun, whether those made daily at fixed observatories or those secured at eclipses, bear upon the solution of one problem: the structure, composition and condition of the sun, from its center to the outermost limits of the coronal streamers.

It is well known to eclipse observers that a regrettably large proportion of observations of these phenomena are failures, or are but partially successful. Some of these unfortunate outcomes are due to nervousness at the critical moment; a psychological state of which some observers know nothing, and against which others are unable to contend. It is a mistake to invite nervousness by attempting to do too much in the limited duration of totality. If seven photographs can be secured with one instrument, working with moderate speed in changing plates, an attempt to secure eight by working under high nervous tension would be a serious error. However, the most prolific source of failure is that of new instruments and new methods used for the first time on eclipse day. It is not an uncommon practise to delay preparations until a few months or weeks before expeditions must depart for their stations; to order new instruments, or new parts of instruments, just in time to have them shipped from factory to station; to use new methods of focusing, etc., for the first time, at the station; and to leave insufficient time for the rehearsal of program after the instruments are in supposed adjustment. It is unnecessary to say that this is cul-

pable management and all wrong. Every piece of apparatus should be set up, adjusted, tested and used at the home station; and time should be available thereafter for making modifications in apparatus, methods and program, and for retrial. With every possible preparation made before leaving home, the astronomer will find his time occupied at the eclipse station in solving the ninety and nine local problems whose coming is sure, but whose nature can not be foreseen. To install half a dozen instruments in a fixed observatory so that they will work satisfactorily, one at a time, and at the observer's leisure, is not a small problem. To construct a temporary observatory in an out of the way corner of the earth, to mount the eight or ten instruments, and to train the dozen or more assistants so that all the instruments and all the men will work together satisfactorily at the fixed instant of totality, is a problem of a very different order. The point which I wish to emphasize is that preparations for observing the eclipse of August, 1905, should begin early in 1904.

COPERNICUS.

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NICOLAUS COPERNICUS was born in Thorn, a town of Prussian Poland, on February 19, 1473. His father, Niklas Koppernigk, was a merchant of Krakau who established himself in Thorn about 1450, and there married Barbara, the daughter of Lucas Watzelrode, a descendant of an old patrician family. The father was chosen alderman in 1465—a testimony of his worth. He had four children: Barbara, who died abbess of the Cistercians at Culm; Katherina, who married a merchant of Krakau; and two sons, Andreas and Nicolaus.

We know little of the childhood of Nicolaus. In 1483 his father died and he was placed in the care of his uncle, another Lucas Watzelrode, who was called to be bishop of Ermeland in 1489, and with whose career that of Copernicus is closely bound up. The boy was educated in Thorn till his nineteenth year, when he was placed in the University of Krakau. The greatest illustration of its faculty was Albertus Blar de Brudzewo (usually written Brudzewski), professor of astronomy and mathematics. The works of Purbach and of Regiomontanus were expounded in his lectures. In the winter semester of 1491–92 Copernicus was matriculated in the faculty of arts, and devoted himself, so it is recorded, with the greatest diligence and success to mathematical and astronomical studies, becoming, at the same time, familiar with the use of astronomical instruments. In the autumn of 1494 Brudzewski left the university, and it is probable that Copernicus did the same. The humanists of the faculty had suffered a defeat at the hands of the scholastics, and the latter now ruled supreme. At Krakau Copernicus studied the theory of perspective, and applied it in painting. Portraits from his hand are praised by his contemporaries.

In the summer of 1496 the youth went to Italy, and in January, 1497, he was inscribed at the University of Bologna, in the 'Album of the German Nation,' as a student of jurisprudence. From 1484 to 1514 the professor of astronomy at Bologna was Dominicus Maria da Novara. He was an observer, a theorist, as well as a free critic of the received doctrines of Ptolemy, although such of his criticisms as we know are not especially happy, it must be confessed. He determined the obliquity of the ecliptic to be 23° 29′ by his own observations, which is in error by 1′ 20″ only, a small quantity for his time. Coper-

nicus was received by him on the footing of a friend and helper, rather than as a pupil; and the association was, without doubt, of great benefit to the younger man. All the systematized knowledge of the time was opened to him; what was known was examined and discussed, not received uncritically. Best of all, observation was practised as a test of theory and as the only basis for its advancement.

The first recorded observation of Copernicus is an occultation of *Aldebaran* by the moon in 1497 at Bologna; in 1500 he observed a conjunction of Saturn with the moon at the same place, and a lunar eclipse at Rome. Other eclipses were observed in 1509, 1511, 1522 and 1523; and positions of Venus, Mars, Jupiter and Saturn in 1512, 1514, 1518, 1520, 1523, 1526, 1527, 1529, 1532, 1537. These recorded observations extend over a period of forty years. Though they are few in number, there is no reason to doubt that they are merely excerpts from a more considerable collection. They were made with very simple wooden instruments constructed by the observer's own hands. One of them, a *triquetum,* was sent as a present to Tycho Brahé in 1584, forty-one years after the death of Copernicus. It was made of pine wood, eight feet long, with two equal cross arms. They were divided, in ink, into 1,000 equal parts, and the long arm into 1,414 parts. This precious relic, together with a portrait of Copernicus, was long preserved in Tycho's observatory at Uraniborg, and finally removed to Bohemia, where it perished in the confusions incident to the Thirty Years' War (1618–48).

Rheticus once urged upon him the need of making astronomical observations with all imaginable accuracy. Copernicus laughed at his friend for being disturbed about so small an error as a minute of arc, and declared that if he were sure of his observations to ten minutes, he would be as pleased as was Pythagoras when he discovered the properties of the right-angled triangle. Copernicus determined the latitude of Frauenburg to be 54° 19½′, which is 2′ too small. This seems to us a large error. Even with his instruments he could have been more precise if he had repeated his observations many times. But the determination was excellent for the times, as we may see by remembering that the latitude of Paris was given by Tycho as 48° 10′, by Fernel as 48° 40′, by Vieta as 48° 49′, by Kepler as 48° 39′. His calculated longitude of *Spica Virginis,* which he took as a standard star, was 40′ in error. He concluded that Krakau and Frauenburg were on the same meridian—an error of 17½′ of arc. The observations of Albategnius, five centuries earlier, were far more precise, and this was not entirely owing to the superiority of the Arab instruments.

At the University of Bologna Copernicus mastered Greek. The knowledge was subsequently utilized in a translation into Latin of the epistles of Theophylactos Simokatta (630 A. D.), which he printed in

1509. This was the only work published by him in his lifetime. The translation is said to be elegant, but the book itself is of comparatively little importance. He had studied it at the university and utilized his knowledge. The book upon which his fame rests—'De Revolutionibus Orbium Cœlestium'—did not appear until the very day of his death, and was published by the care of others. Scipione dal Ferro, the discoverer of the general method of solving the cubic equation, was in residence at Bologna at the same time, and there is little doubt that Copernicus met him also, although there is no record of the meeting. In recording this name we seem to be well out of the middle age. A general solution of the cubic belongs to the modern period, although the Arabs were working on the question in the tenth century.

In 1497 Copernicus was appointed Canon of Frauenburg, which assured to him, for life, an income corresponding to about $2,250 of our money of to-day, and a leave of absence of three years was granted him to continue his studies in Italy. At a later date he also received a sinecure appointment at Breslau. He had already taken the lesser vows; to the higher he never was dedicated. In 1499 his brother Andreas was likewise consecrated Canon of Frauenburg, and he also matriculated at Bologna (1498) in the faculty of law. Both brothers were represented at home by substitutes, and considerable expense may have attached to this, but it is curious to note that on account of the 'costly living' at the university they needed, and received, remittances from the bishop, their uncle.

In the summer of 1500 his leave of absence expired, and in company with his brother he crossed the Alps to Frauenburg, where both received a new permission to return to Italy. It was stipulated that Nicolaus should study medicine after the completion of his courses in law, in order that he might serve as physician to the Frauenburg chapter. In the autumn of 1501 both brothers were again in Italy, Andreas at Rome, Nicolaus at Padua. The doctor's degree in jurisprudence was conferred upon Nicolaus in 1503, but he remained in Italy till the year 1505 or 1506—nine or ten years in all.

In the archives of Ferrara we read:

1503. Die ultima mensis Maij. Ferrarie in episcopali palatio, sub lodia horti presentibus testibus vocatis et rogatis Spectibili viro domino Joanne Andrea de Lazaris siculo panormito almi Juristarum gymnasii Ferrariensis Magnifico Rectore, Ser Bartholomeo de Silvestris, cive et notario Ferrariensi. Ludovico quondam Baldassaris de Regio cive Ferrariensi et bidello Universitatis Juristarum civitatis Ferrarie, et alijs.

m: Venerabilis, ac doctissimus vir Nicholaus Copernich de Prusia Canonicus Varmensis et Scholasticus ecclesie S. crucis Vratislaviensis: qui studuit Bononie et Padue, fuit approbatus in Jure canonico nemine penitus discrepante, et doctoratus per prefatum dominum Georgium Vicarium antedictum etc.

promotores fuerunt
D. Philippus Bardella et
D. Antonius Leutus qui ei dedit insignia } cives Ferrariensis etc.

In the year 1500 Copernicus delivered lectures at Rome before an audience of two thousand hearers, the Archbishop of Mechlin declares. These lectures could not have announced the heliocentric theory, which dates from the year 1506 only, nor could they have been before the university, because Copernicus did not take the degree that admitted him to the privilege of teaching until 1503. He took no degree at Krakau, so far as is known.

Copernicus was now quite free to prosecute his studies in medicine, which he combined with philosophy. The celebrated Pomponazzi was then a member of the faculty, in the prime of his vigor. He had taken his degrees in philosophy and medicine at Padua in 1487, and in the next year, when he was but twenty-six years of age, had been chosen extraordinary professor. It was a custom of those days to choose two professors of each subject in order that their public disputations might stimulate their hearers to independent thinking. The ordinary professor of philosophy was Achillini—a veteran of the strict school of Aristotle.

Pomponazzi remained at Padua until the university was closed in 1509; and in Ferrara till 1512, when he removed to Bologna, where in 1516 he wrote his famous treatise on the 'Immortality of the Soul'—the foundation of his character as a skeptic and of his fame as a philosopher. Into his doctrines it is not necessary to enter at length. Briefly they are that man, standing on the confines of two worlds—the material and spiritual—necessarily partakes of the nature of both. Man is partly mortal (since the human soul depends in some degree on matter) and partly immortal. The soul is, Pomponazzi says, absolutely mortal, relatively immortal. This doctrine was, of course, a denial of the theory of the Roman church. He was vehemently attacked. His book was burned in Venice. Powerful friends among the cardinals protected him in Rome. His university stood by him and confirmed him in his professorial chair for eight years, and increased his salary to 1,200 ducats.

Pomponazzi was a thinker of essentially modern spirit. Reason, he said, was superior to any authority. If, in his teaching of Aristotle, he should find himself in error, "ought I," he says, "to interpret him differently from my real sentiment? If it is said—the hearers are scandalized—well, be it so. They are not obliged to listen to me, or to forbid my teaching. I neither wish to lie, nor to be false to my true conviction." He decides, on psychological grounds, against the immortality of the soul, and then proceeds to build up a system of

practical ethics resting on philosophy. Belief is not needed as a basis for ethics—not by cultured men, at any rate. He is the first writer within the christian communion to attempt to establish morality on a foundation of reason. He is a Stoic. "The essential reward of virtue is virtue itself," he says; "the punishment of the vicious is vice, than which nothing can be more wretched and unhappy." Future rewards and punishments are not invoked.

It is worth our while to pause here and reflect that we are hearing a teacher to whom Copernicus listened; to whom all Italy, nay all Europe, attended. This teaching was permitted in Italy. It influenced thousands upon thousands of hearers. Perhaps the tolerant treatment of Lutherans in Ermeland by Copernicus when administrator of his diocese may have had its origin in ideas received at this time.

There were other men in the faculty with a message for pupils of genius. Aristotle and Plato were expounded from original Greek texts, and the mazy fabrics of the commentators were swept away. Fracastor, who was, by and by, to become an opponent of the heliocentric theory, was a teacher there. He was the first to teach that the obliquity of the ecliptic changed uniformly (1538), in which respect—only—his doctrine was more sound than that of Copernicus. Medicine was expounded by four professors, and dissection of the human body was practised. Marc Antonio della Torre, the instructor of da Vinci, was one of the anatomists. So far as is known, Copernicus did not take his doctor's degree in medicine.

He was, however, skilled in physick, after the fashion of his day, and practised the art during all his life. He was considered, some of his biographers say, 'a second Æsculapius.' We know nothing definite of his medical practise until his later years. From 1529 to 1537 he treated Bishop Ferber, who praises him as the preserver of his life. Duke Albrecht of Prussia called him to Königsberg in 1541 to treat one of his court, and it is of record that the patient recovered.

It does not appear that Copernicus returned to Frauenburg before 1506. He was then thirty-three years of age. All that the world had then to offer in the way of culture was his. He had followed university studies in theology, philosophy, logic, medicine, mathematics and astronomy. He had mastered Greek, and practised painting. He had been the friend or pupil of the greatest teachers of Italy for ten years, and was now established as physician to his uncle in the bishop's palace at Heilsberg, in high station, with an assured income. Up to this period he had shown no original power; but there can be no doubt that he was universally regarded as a man of the highest culture.

His relation to his uncle was that of Achates to Æneas, affectionate

and intimate. The bishop of Ermeland was a great noble in a place of power. Affairs of much import to the church had to be treated. The knights of the Teutonic order (founded at Acre in 1190) had conquered the Duchy of Prussia in the thirteenth century. West Prussia had been ceded to Poland in 1466, while East Prussia, including Ermeland, was a Polish fief. A part of the policy of the order was to extend the lordship of their metropolitan Bishop of Riga over the diocese of Ermeland. It was the policy of Bishop Lucas to oppose all such efforts, to attain entire independence, and even to become spiritual over-lord of a part of the territory of the Teutonic order. These plans came to nothing; but a legacy of hatred remained among the knights, who left nothing undone to provoke and degrade the Ermeland bishop and his friends, and to excite disorder in his own territory. The pressure of the invading Tartars on the borders kept the knights occupied, however, and left them little leisure for hostile action. Constant vigilance was required on the part of the bishop, and many journeys to different parts of the bishopric were required.

Copernicus was charged with missions of this sort from the very first. It was during one of these journeys to Petrikau in 1509 that he printed his Latin version of the 'Epistles' of Theophylactos. Greek epistles—invading Tartars—feudal rights—church privileges—Polish and Prussian politics—these were the preoccupations of his mind. We can hardly think that much time was left for astronomy, yet the lunar eclipse of June 2, 1509, was duly observed. One of Copernicus's biographers calls him 'a quiet scholarly monk of studious habits—in study and meditation his life passed—he does not appear as having entered into the life of the times.' This is the legend. It is obviously only a small part of the truth. In March, 1512, the bishop of Ermeland died and Copernicus returned to his cloister at Frauenburg. He was now thirty-nine years old.

In the dedication of his 'De Revolutionibus' to the Pope (1542), Copernicus says that it is now 'four nines of years' since the heliocentric theory was conceived. Strictly interpreted this brings the date of its birth to 1506. It is, at all events, safe to say that the idea was elaborated on German, though it may have been born on Italian, soil.

From 1512 to 1516 Copernicus was in constant residence at the Cathedral of Frauenburg, where indeed the greatest part of his life was spent. For two periods (1516–19 and 1520–21) he lived at Allenstein, administering certain estates belonging to his chapter. His observatory was on one of its towers and commanded a wide horizon. Few observations were necessary for his great discovery of the heliocentric motion. He knew beforehand the phenomena to be explained. Ptolemy had offered a solution that had been accepted for fourteen

hundred years. Would any other hypothesis explain them? In the first place, Copernicus affirms the rotation of the earth on its axis. The rising and the setting of the stars is caused by this.

The question of the rotation of the earth had been examined by Ptolemy. He rejects the notion, saying: "If the earth turned in twenty-four hours around its axis every point on its surface would be endowed with an immense velocity, and from the rotation a force of projection would arise capable of tearing the most solid buildings from their foundations and of scattering their fragments in the air." The force of projection depends, we know, not only on the absolute velocity of points on the turning earth (and this velocity is immense), but also on the angular velocity about this axis. The latter is slow. The hour hand of a clock turns twice as fast as the earth. The projective force at its maximum is just sufficient to diminish the weight of a ton by six pounds. A feeble force of the sort is not fitted to tear trees up by their roots or buildings from their foundations, as Ptolemy supposed.

Copernicus adopted the theory of a rotating earth, although he was no better able than Ptolemy to explain the difficulty. The science of mechanics was not born till the time of Galileo. The reasoning of Copernicus is: "The rotation of the earth being a natural movement, its effects are very different from those of a violent motion; and the earth, which turns in virtue of its proper nature, is not to be likened to a wheel that is constrained to turn by force." He seeks to escape the difficulty by a trick of scholastic philosophy. No other issue was open in his day. Examples of this sort are well fitted to give us a vivid idea of the state of science in those times. It was not easy for our predecessors to take a forward step. More honor to them that the steps were taken.

In the preface to the 'De Revolutionibus' Copernicus declares that he was dissatisfied with the want of symmetry in the theory of eccentrics and weary of the uncertainty of the mathematical conditions. Searching through the works of the ancients, he found that some of them held that the earth was in motion, not stationary. Philolaus, for example, taught that the earth revolved about a central fire.* Copernicus makes no mention of the theory of Aristarchus. We must assume that he did not know it, though his ignorance in this respect is hard to explain. We have no list of his library, which was, however, extensive for the time.

"Then I too," says Copernicus, "began to meditate concerning the motion of the earth; and although it appeared an absurd opinion, yet since I knew that, in earlier times, others had been allowed the privilege of imagining what circles they might choose in order to explain

* The central fire of Philolaus was, however, not the sun; for in his theory the earth, the sun, the moon and all the planets revolved about a fire so placed at the center of the system as to be forever invisible to the earth.

the phenomena, I conceived that I also might take the liberty of trying whether, on the supposition of the earth's motion, it were possible to find better explanations of the revolutions of the celestial orbs than those of ancient times. Having then assumed the motions of the earth that are hereafter explained, by long and laborious observation I found at length that if the motions of the other planets be likened to the revolution of the earth, not only their observed phenomena follow from the suppositions, but also that the several orbs, and the whole system, are so connected in order and magnitude that no one part can be transposed without disturbing the rest and introducing confusion into the whole universe." He looked, he here says, for a new theory because the old one was unsymmetric; and his new theory satisfies because it consistently explains the facts of observation and because it was symmetric. Symmetry of the kind referred to is not essential to a true theory. If any theory explains every fact of observation quantitatively as well as qualitatively, it is to be accepted. Copernicus was not free from hampering presuppositions any more than his predecessors.

"We must admit," he says, "that the celestial motions are circular, or else compounded of several circles, since their inequalities observe a fixed law, and recur in value at certain intervals, which could not be unless they were circular; for the circle alone can make that which has been recur again." In writing this passage his mind was closed to every idea but one. Copernicus knew, far better than most of us, that ovals and ellipses might also serve to represent recurring values, but the thought did not even cross his mind in connection with celestial motions. He was committed to circular motions exclusively, from the outset.

"We are therefore not ashamed to confess," he says, "that the whole of the space within the orbit of the moon, along with the center of the earth, moves around the sun in a year among the other planets; the magnitude of the world (solar system) being so great that the distance of the earth from the sun has no apparent magnitude (is indefinitely small) when compared with the sphere of the fixed stars. . . . All which things, though they be difficult and almost inconceivable, and against the opinion of the majority, we, in the sequel, by God's favor, will make clearer than the sun, at least to those who are not ignorant of mathematics."

The system of Copernicus required thirty-four circles and epicycles —four for the moon, three for the earth, seven for the planet Mercury and five for each of the other planets. Cumbrous as this apparatus appears to us, it was a distinct simplification of the Ptolemaic system as taught in the sixteenth century. Fracastor, writing in 1538, employed sixty-three spheres to explain the celestial motions.

One word must be said of the theory of *trepidation* which Coper-

nicus accepted. The precession of the equinoxes was discovered by Hipparchus by comparing his own observations of stars with preceding ones. He saw that the longitudes of the stars changed progressively and fixed the annual change as 1° in seventy-five years. Later observers determined the amount of precession by comparing their own observations with preceding ones. The motion of the origin of longitudes—the equinox—is really uniform. An unlucky Jew—Tabit ben Korra—in the ninth century, came to the conclusion that the motion was not uniform, but variable, sometimes at one rate, sometimes at another. The variable motion was the trepidation. Copernicus admitted the reality of this phenomenon and thereby introduced a fault. Tycho Brahé, who had no important data on this point that was inaccessible to Copernicus, rejected the idea of trepidation and freed astronomy from a blemish that had endured for centuries.

It is impossible and unnecessary to exhibit in this place the details of the heliocentric theory of Copernicus. In Kepler's account of Copernican astronomy there is a section on the explanation of the retrogradations of the planets. "Here," he says, "is the triumph of the Copernican astronomy. The old astronomy can only be silent and admire; the new speaks and gives rational account of every appearance; the old multiplies its epicycles; the new, far simpler, preserves everything by the single motion of the earth around the sun." In describing the stationary points of the planets he declared: "Here the old astronomy has naught to say."

We must try to put ourselves in the place of the students of those days who heard the two explanations of the world—the geocentric and the heliocentric—expounded by the same professor in the same lecture-room as alternative hypotheses. Each hypothesis offered a possible explanation. That of Copernicus was so simple that its intellectual acceptance was immediate. It was possible; but was it true? If it were accepted, what implications did it bring in its train? The real difficulty was moral, not intellectual. Was the whole edifice of Ptolemy to be destroyed? No—some of it was indubitably true. If some, why not all? What was to become of the authority he had held for a thousand years? Was all knowledge to be made over? Even the idea that part of the 'Almagest' was true and part false was not to be lightly accepted.

The conception that every physical problem has one and only one solution was also entirely new; until it was fully received students balanced one explanation against another, and even held two at once, strange as this may seem to us with our new standards in such matters. The heliocentric theory eventually prevailed not because the logic of Ptolemy was broken down, but because all mere authority was weakened. The dicta of philosophers were looked at in a new light. It was

not, in fact, generally received until the day of Newton, though it was sufficiently established by the observations of Galileo and convincingly by the calculations of Kepler. To actually demonstrate the rotation of the earth on its axis we must have recourse to an elaborate experiment like that of Foucault on the pendulum, or to comparisons of the force of gravity in different latitudes; to demonstrate its revolution round the sun it is necessary to measure the time required for light to reach us from the distant planets, or to evaluate the aberration of the light of the fixed stars. It was not easy for the sixteenth century to make a decision. If the heliocentric theory were true, then the planet Venus must show phases like the moon; but no phases could be seen. It required Galileo's telescope to show them. Moreover, the fixed stars must have annual apparent displacements in miniature orbits. None such were visible; none were detected until 1837, when Bessel determined the parallax of a fixed star (61 *Cygni*) for the first time. Galileo sought for them in vain; so did Herschel; so did other astronomers of the eighteenth century with their splendid instruments. The conception of epicycles was retained in the 'De Revolutionibus,' and it seems to us a blemish; to the contemporaries of Copernicus it was a mere analytic device. Newton explains one of the inequalities of the moon's motion by an epicycle, in the 'Principia.'

It is only when we thus consider in detail how the new ideas must have presented themselves to the students of the sixteenth century that we can comprehend the real obstacles in the way of their acceptance. A genius like Kepler could receive them simply on their intellectual merits. Men in general required time to change their point of view, and to accept a novel and essentially disheartening theory. Ptolemy's system of the world was compendious, comfortable, so to say, and easily understanded of the people. Man's central position in the universe flattered his pride and allayed his fears.

Peter the Lombard (1100–60) expresses the accepted view in its baldest form: 'Just as Man is made for the sake of God, that is, that he may serve him, so the Universe is made for the sake of Man, that is, that it may serve him; therefore is Man placed at the middle point of the Universe, that he may both serve and be served.' The new view made man an outcast and placed him in immense and disquieting solitudes. Pascal has phrased the new and anxious fear: 'Le silence éternel de ces espaces infinis m'effraie.'

Astronomers needed accurate tables of the planetary motions in order to predict eclipses and conjunctions. The Alphonsine tables were quite unsatisfactory. The theory of Copernicus was made the basis of new tables—the Prutenic tables—by Reinhold in 1551, and they remained the standard until 1627, when the Rudolphine tables, based on Kepler's theories and Tycho's observations, superseded them.

The doctrines of Copernicus were spread by means of almanacs based upon Reinhold's tables rather than by his theoretical works; and they made their way quietly, surely and without any great opposition. Tycho proposed a new (and erroneous) system of the world in 1587. It also had its effect in weakening the authority of Ptolemy. The motions of comets began to be observed with care. It was clear that the doctrine of material crystal spheres would not allow room for their erratic courses. In one way and another the authority of the ancients was broken down and the way prepared for the eventual triumph of the theory of Copernicus.

It is interesting to note the opinions of Englishmen of the sixteenth and seventeenth centuries. Francis Bacon rejected the new doctrines; Gilbert of Colchester, Robert Recorde, Thomas Digges and other Englishmen of the time of Queen Elizabeth, accepted them. Milton seems to hesitate in 'Paradise Lost' (book viii.), which was written after 1640, though he had visited Galileo in Florence in 1638, where, no doubt, Galileo proved the Copernican theory to him by word of mouth. At all events he thoroughly understood it as his description of the earth

. . . that spinning sleeps
On her soft axle, while she paces even
And bears thee soft with the smooth air along,

abundantly proves, since in the last line one of the chief objections to the theory is answered.

The heliocentric theory gained powerful auxiliaries in Moestlin, professor of astronomy at Tübingen, and in his pupil Kepler. In 1588 Moestlin printed his 'Epitome,' in which the mobility of the earth is denied; but he accepted the new views probably as early as 1590. Kepler writes: "While I was at Tübingen, attending to Michael Moestlin, I was so delighted with Copernicus, of whom he made great mention in his lectures, that I not only defended his opinions in our disputations of the candidates, but wrote a thesis concerning the first motion which is produced by the revolution of the earth." In 1596 Moestlin, in a published epistle, expressly adhered to the heliocentric theory of the world.

Luther emphatically declared his opinion of the Copernican theory on several occasions. He calls Copernicus 'that fool' who is trying to upset the whole art of astronomy; and refers to Joshua's command that the sun should stand still as a proof that the earth could not possibly be the moving member of the system. Melanchthon, a far more learned man, declared that the authority of scripture was entirely against Copernicus. The attitude of the Roman Church was more indifferent at that time, not more tolerant. Tolerance comes with enlightenment; and both protestant and catholic doctors were, in gen-

eral, profoundly ignorant of science. When we are thinking of the attitude of the church we must remember that the conflict with Galileo had not arisen. Calvin quotes the first verse of the ninety-third Psalm

—*The world also is established, that it can not be moved*

and says: 'Who will venture to place the authority of Copernicus above that of the Holy Spirit?'

Such dicta of great theologians are often quoted to demonstrate the existence of an age-long conflict between science and religion. So to interpret them is a sad misconception of the real warfare that has occupied mankind for ages. The veritable conflict has been between ignorance and enlightenment, not in one field only, but in all conceivable spheres.

Before there can be fruitful discussion the 'universe of discourse' must be defined. Things of a like kind can alone be compared. The world of science relates and refers to material things moved by physical forces; and only to these. The world of religion relates and refers only to immaterial things moved by spiritual energies. These worlds are wide apart now. They were widely separated even in the sixteenth century, and they were entirely divided for the highest thinking men even in the middle ages. In either world conflicts are possible. They can only take place between ideas of the same kind; between religion and heresy, or between science and pseudo-science. Theologians decide the issue in one world; men of science in the other. It is the business of philosophers to define and discuss the limits of each world in turn; to determine the validity of conclusions. It is the privilege of poets harmoniously to express imagined analogies between the action of spirit on spirit and of force on matter. It is the dream of seers and prophets to synthesize such analogies into a single system, mingling two universes into one. Whatever may be our hope for the future, the synthesis has not yet been achieved. Theologians have essayed it from one direction, philosophers from another, but the essential distinction remains untouched. There is a world of matter; there is a world of spirit. Men live in both. Their actions are ruled by different and discrepant laws. In the world of spirit the good man is safe and happy, no matter what fate may befall him in the world of physical phenomena. In the latter world no virtue will save the man who transgresses its especial laws. Gravitation, and not goodness, decides whether his falling body suffers harm or is preserved alive.

To Calvin the pronouncement of Copernicus was sheer blasphemy. It seemed to him to lie entirely within the sphere of religion. Judged by the accepted standards of that sphere it was audacious heresy. To Kepler the law of Copernicus lay entirely within the sphere of science. It was to be accepted as true, or rejected as pseudo, science entirely by

scientific criteria. Calvin's words fell within one universe of discourse, Kepler's in another. There was no conflict between religion and science as such. Calvin sat as judge of a conflict between religion and a possible heresy. Kepler asked himself if this new assertion was substantial truth or merely error masquerading in a scientific form. Phenomena can not be judged by criteria belonging to a world to which they are foreign. It is in a light like this that we must examine the relations of such men as Copernicus and Galileo to their times.

The Lateran council (1512–17) appointed a committee to consider the much needed reform of the Church calendar, and in 1514 the help of Copernicus was asked—a proof that he was not only remembered in Rome, but that his reputation had grown since his residence there. He declined to give advice, for the reason that the motions of the sun and moon were, as yet, too imperfectly known. At the request of the chief of the committee, Copernicus continued his researches on the length of the tropical year—a fundamental datum.

In November, 1516, the quiet life of Copernicus at Frauenburg was broken up by his appointment as *Administrator bonorum communium* at Allenstein. The appointment was for one year, but the administration of Copernicus was so successful that he occupied the post during the years 1516–19 and again in 1520–21. His manifold duties in this place brought him again into conflict with the Teutonic knights. The interests of the order and of the church in Ermeland were totally antagonistic. At times open hostilities occurred and towns were besieged, taken and plundered. It is not necessary to follow this harassing strife into the details of Prussian and Polish politics. It is recounted in history as the *Fränkischer Reiterkrieg.* In 1521 Copernicus, then the recognized head of his chapter, was selected to draw up a statement of grievances against the order to be laid before the estates of Prussia. The lands of the chapter of Frauenburg had been overrun, the towns and villages plundered, the peasants had fled or had been killed. The castle of Allenstein, the residence of Copernicus, was itself in danger until it was saved by a four years' truce concluded at Thorn. In such stormy times astronomy was not to be thought of.

It was at this period that Copernicus composed, at the request of the Prussian estates, a memorial on the debasement of the coinage of the country and on the remedies to be adopted. "Money," he says, "is a measure, and like all measures it must be constant in value. What would one say to a yard or a pound whose values could be changed at the will of the measure-makers? The value of money depends not on the stamp it bears, but on the value of the fine metal it contains." Nothing could be clearer than this. His conclusions on the effects of a debased currency on the interests of landlord and tenant are not so

sound. Copernicus also proposed to coin all the money of Prussia at a single mint, forbidding the towns to use their ancient privileges, which had been abused. This proposal, as well as others made in the years 1521–30, failed chiefly because Dantzig and other towns were not willing to relinquish vested rights. It is interesting to note that in his memorial of 1526 he sets the ratio of gold and silver as 1 to 12.

Bishop Fabian died in 1523. During the ensuing vacancy Copernicus was chosen administrator of the diocese. His duties were harassing. The troops of the order encroached more and more on the church holdings. The Lutheran heresy was also a source of anxiety. The steps taken by the administrator were marked by great tolerance. Before the preaching of the new faith was forbidden outright it was enjoined that it should be refuted by argument. A new bishop, Mauritius Ferber, was chosen in 1523, and a word must be said of the bishop's nephew and coadjutor, Tiedemann Giese. Born in 1480, he became canon of Frauenburg about 1504, and was the intimate and affectionate friend of Copernicus during the whole of his life. It was to him that Copernicus confided the manuscript of his great work in 1542. Bishop Ferber died in 1537, and Bishop Dantiscus of Culm was chosen in his place, while Giese by a compromise became bishop of Culm.

The last observation recorded by Copernicus in the 'De Revolutionibus' is dated 1529. From this we may infer that his great work was essentially completed at that time, though it was repeatedly revised afterwards. It had been begun twenty-three years earlier. It was not published until 1543, though its doctrines had been freely communicated to scholars and friends. In 1531 a set of strolling players, set on, it is said, by his enemies among the Teutonic knights and among the Lutherans, gave a little show at Elbing ridiculing the notion that the earth moved round the sun. The play was devised by a certain Dutchman who afterwards became rector of the gymnasium at Elbing. That its satire was understood by the common people proves the opinions of Copernicus to have been fairly well known by his neighbors even at that epoch when absolutely nothing had been printed concerning them. About 1530 a manuscript commentary on the hypotheses of the celestial motions had been prepared by Copernicus for private circulation among men of science in advance of the publication of 'De Revolutionibus.' Two copies of this manuscript still exist, one at Vienna, one at Upsala. At the end of it a *résumé* of his new doctrine is given in seven axioms. (I.) There is only one center to the motions of the heavenly bodies; (II.) this is not the earth about which the moon moves, but (III.) it is the sun; (IV.) the sphere of the fixed stars is indefinitely more distant than the planets; (V.) the diurnal motion of the sun is a consequence of the earth's rotation;

(VI.) the annual motion of the sun and (VII.) the motions of the planets are, primarily, not due to their proper motions.

In 1533 Copernicus was sixty years old and applied for a coadjutor. His duties were, at this time, made light for him. In 1532 an observation of Venus is recorded. Other observations were made in 1537. In 1533 he observed the comet of that year. It may be surmised (his memoir on the comet is not extant) that the retrograde motion of this heavenly body confirmed in his mind his criticisms of the system of Ptolemy.

The theory of Copernicus began to be known in Rome, and it was well received. In 1533 Widmanstad, secretary to Pope Clement VII., gave a formal explanation of the heliocentric theory of Copernicus to the pope and to an audience containing several cardinals and bishops. There is no doubt that the theory was received with interest. There is no sign of opposition, and Widmanstad subsequently obtained high honors in the church. The attitude of the Lutherans was, as we have seen, very different. The cardinal-bishop of Capua wrote in 1536 to Copernicus begging him for an explanation of his system.

In 1537 Dantiscus became bishop of Ermeland. All the canons of Frauenburg, Copernicus included, supported his nomination. Copernicus was known, however, to be a warm friend of Giese, who should have succeeded, as coadjutor, to his uncle's bishopric, but who was elected to that of Culm by a compromise. Difficulties soon arose between Copernicus and his new bishop, and the breach was widened in various ways. The bishop, himself a man of loose morals, ordered Copernicus to send away his housekeeper, on the assumption of illicit relations between the two, and kept the accusation alive by various official letters. Bishop Dantiscus oppressed Copernicus in various ways and remained his enemy in spite of certain advances on the part of the latter. If Copernicus ever feared the persecution of the church on account of his scientific teaching—of which there is little evidence—it was because his bishop stood ready to use every and any weapon against him.

Copernicus gained an ardent disciple in George Joachim of Rhaetia, known to us as Rheticus. He was born in 1514 and made his studies at Nuremberg under Schoner to such effect that he was appointed to be professor of mathematics at the University of Wittenberg in 1537, at the age of twenty-three. In May, 1539, he visited the great astronomer of Frauenburg chiefly to study his doctrines of trigonometry, and his trigonometric tables. Copernicus was then sixty-six years of age and his enthusiastic and loyal guest was twenty-five. He was received cordially and at once set himself to study the manuscripts of Copernicus. His visit extended itself from a few weeks to more than two years, and he

became a firm believer in the new heliocentric astronomy, which he was well prepared to receive and to expound.

A letter from Rheticus, written a few months after his arrival at Frauenburg, affords one of the very few personal views of Copernicus that have come down to us. The letter was published with a long Latin title, in 1540, and is known as 'Narratio Prima.' "I beg you to have this opinion concerning that learned man, my preceptor: that he had been an ardent admirer and follower of Ptolemy; but when he was compelled by phenomena and demonstration, he thought he did well to aim at the same mark at which Ptolemy had aimed, though with a bow and shafts of very different material from his. We must recollect what Ptolemy has said: 'He who is to follow philosophy must be a freeman in mind.'" "My preceptor was very far from rejecting the opinions of ancient philosophers from love of novelty, and except for weighty reasons and irresistible facts. His years, his gravity of character, his excellent learning, his magnanimity and nobleness of spirit are very far from any such temper (of disrespect to the ancients)." This letter, addressed by Rheticus to his old master Schoner, was the first easily accessible account of the new theory. The life-giving sun, he says, is placed in its appropriate place, and a single motion of the earth explains all the planetary motions. All is harmony as if they were bound together with a golden chain. He praises the great simplicity and reasonableness of the new doctrine, as well as the almost divine insight and the uncommon diligence of the master. He had formerly no idea, he says, of the immense labor required in such works, and the example of Copernicus leaves him in astonishment. Copernicus had made a complete collection of all known astronomical observations, and by these his theory was tested. The master was not content until every hypothesis had been fully proved.

Rheticus showed his admiration for Copernicus not only in these public, but also in private, ways. Books that he presented to the master (which are often annotated by Copernicus's own hand) are still to be found in various libraries of Sweden, where they were taken after the plundering of Ermeland in the thirty years' war. At Wittenburg Rheticus and his colleague Reinhold, Copernicans both, were by the conditions of their professorships obliged to teach the Ptolemaic system, just as Galileo, at Padua, a Copernican, had to confine himself to the exposition of Sacrobosco. It may safely be surmised, however, that their pupils did not leave them without hearing something of the true doctrines. In the 'Narratio,' Rheticus, who was a firm believer in astrology, uses the data of the 'De Revolutionibus' as bases for wide-reaching astrological predictions. They are of no interest in themselves, but as the letter was written under the eye of Copernicus, they lead to the conclusion that they were not disapproved by the latter.

So far as I know, this is the only evidence for the belief of Copernicus in astrology. We have no horoscopes from his hand but, like all his contemporaries, he probably gave it a place among the sciences.

Rheticus deserves the gratitude of all calculators for his table of trigonometric functions (sines, tangents, secants) to ten decimal places, for every 10″ of the quadrant, published in a huge volume by his pupil, Otho, under the title 'Opus Palatinum de Triangulis.' The tables of Rheticus are the basis upon which Vlacq founded his great tables, and they have served as models for many followers. Lansberg's tables appeared fifteen years after the 'Opus Palatinum' and lightened the immense labors of Kepler.

Toward the end of the year 1541 Rheticus returned to Wittenberg carrying with him a part of Copernicus's manuscript—a treatise on 'Trigonometry'—which he printed in 1542. The complete manuscript of the 'De Revolutionibus' was sent by Copernicus to his old friend Giese, the bishop of Culm, for such disposition as he thought best. The bishop sent it to Rheticus to arrange for its printing at Nuremberg, and to see it through the press. It fell out that the printing had to be confided to Andreas Osiander, a Lutheran minister interested in astronomy. The book was published early in 1543, and a copy reached Copernicus on May 24, the very day of his death.

Osiander prefixed to the volume an introductory note which he did not sign, as follows:

> Scholars will be surprised by the novelty of the hypothesis proposed in this book, which supposes the earth to be in motion about the sun, itself fixed. But if they will look closer they will see that the author is in no wise to be blamed. The aim of astronomy is to observe the heavenly bodies and to discover the laws of their motions; the veritable causes of the motions it is impossible to assign. It is consequently permissible to imagine causes, arbitrarily, under the sole condition that they should represent, geometrically, the state of the heavens, and it is not necessary that such hypotheses should be true, or even probable. It is sufficient that they should furnish positions that agree with observations. If astronomy admits principles, it is not for the purpose of affirming their truth, but to give a certain basis for calculation.

The best authorities affirm that Osiander's apology, which he had suggested to Copernicus as early as 1540, was unauthorized.

Osiander made many changes in the text also, and added the last two words of the title under which the book was printed—'De Revolutionibus Orbium Cœlestium.' Readers of our day universally interpret the apology to be an attempt to forestall theological opposition and persecution. They remember the conflict of Galileo with the church. But Osiander was a protestant divine, Copernicus a catholic priest. It is passing strange to conceive that a Lutheran schismatic should intervene to shield an orthodox catholic from accusations of heresy. Moreover, Copernicus had good reasons for believing that the princes of the

church would receive his work favorably. His doctrine had been known to them since 1530. He knew, however, that several powerful university teachers—Fracastor for one—opposed it. Ought we not to interpret the apology as an address to men of science? Whewell justly remarks that Copernicus seems to consider the opposition of divines as a 'less formidable danger' than that of astronomers. It is difficult to admit that Osiander dared to prefix this note without the authorization of Copernicus, or, at least, of Rheticus. There seems to be no reason to doubt that it was addressed solely to men of science.

The words of the apology represent the exact point of view of the ancients, and are entirely opposed to the attitude of modern science. Centuries of experience have taught the modern world that there is one and only one solution to a scientific problem. Modern science is a search for such unique solutions. Anything less definite is an hypothesis to be held tentatively and temporarily, it may be even alternatively with another, or others. The theories of the Greek philosophers were, in general, held by them primarily as hypotheses. Their whole attitude towards scientific certainty was thus entirely different from our own. In the time of Copernicus the minds of most men were cast in the ancient temper. It is, in fact, from his century that the new insight dates. This is not to say that colossal geniuses like Archimedes or Roger Bacon did not work in what we call the modern spirit. It is simply to confirm that most of the contemporaries of Copernicus belonged, in this respect, to the ancient world. The apology expressed exactly their attitude. The attitude and temper of the modern world are entirely different; they are perfectly formulated in these words of Pascal: "Ce n'est pas le décret de Rome sur le mouvement de la terre qui prouvera qu'elle demeure en repos; et, si l'on avait des observations constantes qui prouvassent que c'est elle qui tourne, tous les hommes ensembles ne l'empêcheraient pas de tourner, et ne s'empêcheraient pas de tourner avec elle."

It required this very book of Copernicus to suggest the pregnant phrase of Pascal.

In the letter of dedication to the Pope—Paul III.—Copernicus speaks in his own name. His words are simple and serious, full of dignity and conviction:

> I dedicate my book to your Holiness in order that both learned men and the ignorant may see that I do not shrink from judgment and examination. If perchance there be vain babblers who, knowing nothing of mathematics, yet assume the right of judging on account of some place of Scripture perversely twisted to their purpose, and who blame and attack my undertaking, I heed them not and look upon their judgments as rash and contemptible.

He is here referring to divines. The following is addressed to astronomers.

> Though I know that the thoughts of a philosopher do not depend on the judgment of the multitude, his study being to seek out truth in all things so far as is permitted by God to human reason, yet when I considered how absurd my doctrine would appear I long hesitated whether I should publish my book, or whether it were not better to follow the example of the Pythagoreans and others who delivered their doctrine only by tradition, and to friends.

The doctrine of Copernicus was first formally judged by the Roman Church in 1615 when Galileo was before the Inquisition in Rome. The judgment was in these terms:

> The first proposition, that the sun is the center and does not revolve about the earth, is foolish, absurd, false in theology, and heretical, because expressly contrary to Holy Scripture.
>
> The second proposition, that the earth revolves about the sun and is not the center, is absurd, false in philosophy and, from a theological point of view at least, opposed to the true faith.

In the year 1616 the works of Copernicus were placed upon the Index 'until they should be corrected,' and 'all writings which affirm the motion of the Earth' were condemned at the same time. The congregation issued a notice to its readers in 1620, thus conceived:

> Although the writings of Copernicus, the illustrious astronomer, on the revolutions of the world have been declared completely condemnable by the Fathers of the Sacred Congregation of the Index, for the reason that he is not content to announce hypothetically certain principles concerning the situation and motion of the earth, which principles are entirely contrary to the sacred Scripture, and to its true and Catholic interpretation (which can absolutely not be tolerated in a Christian man) but dares to present them as indeed true; nevertheless, because this book contains things very useful to the republic, it has been unanimously agreed that the works of Copernicus ought to be authorized, so far printed, as they previously have been authorized, correcting, however, according to the following notes, the passages in which he does not express himself hypothetically, but affirmatatively maintains the motion of the earth; but those which, in future, will be printed must not be so printed save with the following corrections, which are to be placed before the preface of Copernicus.

The corrections follow; they are not numerous or important.

The works of Copernicus were still on the Index in the year 1819. In the following year Pope Pius VII. approved a decree of the Congregation of the Holy Office that the Copernican system, as established, might be taught, and in 1822 'the printing and publication of works treating of the motion of the earth and the stability of the sun, in accordance with the general opinion of modern astronomers, is permitted at Rome.' Centuries before this date the real question had been judged; but its formal settlement in the Roman Church was postponed to our own day.

The judgments of the Congregation of the Index upon the heliocentric theory were an incident in the history of the relations of Galileo with the authorities at Rome, and they can best be understood in con-

nection with that history. Something, however, may be said of them here. It is to be observed that the first proposition is condemned because it is contrary to scripture, heretical, false in theology, *absurd* and *foolish;* and the second because, from a theological point of view it is opposed to the true faith, *false in philosophy* and *absurd.* The words not in italics relate to judgments upon points of doctrine. The words in italics relate to judgments upon matters of philosophy or of science.

It was entirely competent for the Congregation of the Index to render decisions upon matters of theology which were binding upon all catholics. The committee was organized and existed for that purpose. Every institution, religious or secular, must decide for itself on matters of the sort. Not to do so is sheer suicide. The competence of the Roman church and of the Congregation of the Index to decide *for itself* questions of what is opposed to its faith, contrary to scripture, false in theology, is not to be denied. This was a conflict of theology with an alleged heresy. Copernicus was a member of the Roman Church. The soundness of his theological opinion was a matter for doctors of theology to settle in their own church in their own way. They did not decide it, however, until they had taken the advice of astronomers who pronounced the heliocentric theory to be baseless. (Delambre, 'Astronomie moderne,' i., p. 681.) Tycho Brahé, also—a great authority—had declared it to be 'absurd and contrary to the scriptures.' These two points are often forgotten by writers of the Martyr-of-Science School.

On the other hand, no one can admit for a moment the right or the competence of the Congregation or of the Church to pronounce final judgment upon a question of philosophy or of science. The whole world is now agreed that it is an impertinence for a body of theologians to pronounce upon a question of science, precisely as it would be for a congress of scientific men to pronounce upon a point of theology.

The reasons that led the Congregation of the Index to take this fatal step must be considered in connection with the history of Galileo. It will not be out of place here, however, to attempt to understand the mistaken point of view of the churchmen responsible for the decision.

For fourteen hundred years the theory of Ptolemy had ruled. In 1543 Copernicus proposed a new and revolutionary system. In its essential point the system was true, as we know now; we also know that it was false in asserting that the planets moved in circular orbits (they really move in ellipses), in accepting trepidation as an incident to precession, and in other matters of the sort. It even asserted, falsely, that the center of the orbit of the earth and not the sun was the center of planetary motion, so that in a strict sense it was not even a heliocentric theory. The theory of Copernicus was not

proved to be true, in its essential feature, until Galileo discovered the phases of Venus, in 1610. Is it any wonder that doctors of the church five years afterwards were not convinced? They were profoundly ignorant of science and not in the least interested in science as such. Any one of them could recollect that Tycho Brahé, the greatest astronomer of his time, had in 1587 made a theory of the world which placed the earth at its center. He, then, did not agree with the theory of Copernicus. He expressly rejected it. It could easily be recollected, also, that in 1597 Kepler had proposed his first theory of the world, in which the planets were arranged according to fanciful and false analogies with the shapes of the five regular solids of Plato. It is now known that the systems of Tycho and of Kepler were both false. Ought the church doctors to have accepted them when they were proposed? In 1609 Kepler proposed a second theory of the world based on elliptic and heliocentric motion. How could the doctors know that this second system was the true one, as indeed it was? Kepler was still alive. How could they know that he would not propose a third theory? They had seen the doctrine of Ptolemy denied by Copernicus; the doctrine of Copernicus denied by Tycho; the doctrine of Tycho denied by Kepler's first system; the doctrine of Kepler's first replaced by that of his second system. All this had occurred within their own memories. In scientific theories as such they had no interest whatever; they were solely concerned for religion. Is it surprising that they did not promptly accept a theory which they did not understand?

It was, however, a profound and inexcusable error for them to condemn it; and by so doing they, unwittingly, dealt a heavy blow to the church. For once, theology engaged in a warfare with science; and the issue was an overwhelming and deserved victory for science. There have not been many such conflicts. Very exceptional conditions are required to bring them about, as may be seen in the long history of Galileo.

It is very difficult to form a vivid conception of the whole character of Copernicus either from his works or from his portraits. We know far too little of his history and too little of the time in which he lived. I have found no summary in any of his biographies that can be called satisfying and I have never been able to make one for myself. I venture to reprint that of Bertrand, and to enclose in parentheses those parts that we positively know to need modification or correction.

Capernic est pour nous tout entier dans son livre. Sa vie intime est mal connu. Ce qu'on en sait donne l'idée d'un homme ferme, mais prudent, et d'un caractère parfaitement droit; tout entier à ses spéculations et comme recuelli en lui-même; il aimait la paix, la solitude, et le silence. Simplement et sincèrement pieux, il ne comprit jamais que la verité pût mettre la foi en péril, et se réserva toujours le droit de la chercher et d'y croire. Aucune passion

ne troubla sa vie; (on ne lui connaît même pas de commerce affectueux et intime*); ennemi des discours inutiles, il ne rechercha ni les éloges ni le bruit de la gloire; indépendant sans orgueil, content de son sort et content de lui-même, il fut grand sans éclat, et, ne se révélant qu'a petit nombre de disciples choisis, il a accompli une revolution dans la science (sans que, se son vivant, l'Europe en ait rien su).†

The system of Copernicus belongs to him alone. It is not the system of Philolaus or of Aristarchus . . . but his own. His name is justly attached to it on account of the care with which he explained its every part, brought out all its phenomena, discovered the causes of these precessional movements which had been known for eighteen hundred years, and explained only by the hypothetical existence of an eighth sphere which made a revolution in 36,000 years around the axis of the ecliptic, while, at the same time, it was constrained to turn daily about the axis of the equator to account for the rising and setting of the stars. It is then Copernicus who really introduced the motion of the earth into astronomy, not merely into academic disputations; it is he who demonstrated how the revolution of the earth about the sun explained the succession of the seasons and the precession of the equinoxes; it is he who showed how simply the retrogradations of the planets are explained by the unequal velocity with which they traverse their concentric orbits about the sun; it is he who put astronomy on new foundations and who opened the way for all later researches. It is to Kepler's enthusiasm over the new truths that we owe the discovery of the true shape of the planetary orbits, and the laws of their motion. The idea of the motion of the earth was unfruitful among the ancients because it was never entertained with seriousness. Its adoption by Copernicus is the beginning of modern astronomy. (Delambre).

The mountain peaks that cluster closely round the Lick Observatory in California are of different heights and were unnamed when the corps of observing astronomers took possession of the newly established station. Names were assigned to them in the order of their heights —Copernicus, Galileo, Kepler, Tycho and Ptolemy. One of the staff of observers, who greatly distinguished himself during his short career at the observatory, objected to the assignment of the name of Copernicus to the highest peak. Copernicus was, no doubt, a great astronomer, he said, but was he preeminent? Should not the highest peak have been assigned to another? The objection is answered the moment the relation of Copernicus to the whole thought of the world is comprehended. His skill as a mere observer, his power as a mere geometer, is not in question. His place is not to be assigned by narrow criteria

* His relations with his uncle and with Giese were both affectionate and intimate; those with the young Rheticus were ideal, considering their ages.

† From the year 1514 onwards his name was widely known among the circles of the learned, and his theories were circulated as early as 1530.

like these. What was the attitude of man towards everything not himself before the day of Copernicus? towards things divine, things spiritual, things natural? What is his view of the world now? The changes are so fundamental, extensive and bewildering as not to be described, much less estimated, except by a long series of separate steps, each one opening new worlds in religion, philosophy, science, art, technics. To name them all would be to summarize the entire history of human progress for three hundred and fifty years. In the long stairway of ascent Copernicus established the foundation stone. Tycho, Kepler, Galileo, Newton, Kant, Laplace, Herschel, Darwin (to speak only of men of science) each laid successive steps upon it. Until the first was firmly laid no building, no advance, was possible. We stand to-day in a high place of vantage won for us by the master builders of more than three centuries. Without Copernicus their work would have been in vain. The modern world is erected upon foundations that he laid.

ON THE SIGNIFICANCE OF CHARACTERISTIC CURVES OF COMPOSITION.

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A FEW months ago, while studying the variation and interrelation of certain sentence constants, as average sentence-lengths, predication averages and simple-sentence frequencies in prose composition, my attention was called to an allied investigation, directed by Dr. T. C. Mendenhall, which takes for its basis the words used by an author rather than the sentences. The investigation in which I was then employed made it clear that the theory which asserts that an author uses invariable average sentence proportions is not true except when modified in essential respects, and I recognized at once that similar modifications would become necessary if the word instead of the sentence were taken as the element of composition.

The allied investigation to which I refer is set forth in two papers by Dr. T. C. Mendenhall, one in *Science,* March 11, 1887, entitled 'The Characteristic Curves of Composition,' the other, 'A Mechanical Solution of a Literary Problem' in THE POPULAR SCIENCE MONTHLY, December, 1901.

These papers deal with the relative frequency of words of different lengths employed by an author. It was found that different groups of a thousand words each, taken from the same author, manifested a rather remarkable uniformity in the frequency of words containing a given number of letters. Larger groups showed still greater uniformity, and hence it was inferred that if sufficiently large groups of words from the same writer were examined, they would yield practically the same relative frequencies of words with a given number of letters.

The results were exhibited graphically. The number of letters per word were used as abscissas, the number of words per thousand containing a definite number of letters were taken for ordinates, and the resulting points connected by straight lines. Thus a graph or diagram was obtained which presents to the eye in a simple manner the relative frequencies of words of different lengths. Two such diagrams from the same author will agree more or less closely, depending upon the number of words in the groups upon which the averages are based. In the writer's own words: "When the number of

words in each group is increased there is, of course, closer agreement of their diagrams, and this became so evident in the earlier stages of the investigation that the conclusion was soon reached that if a diagram be made representing a very large number of words from a given author, it will not differ sensibly from *any other diagram* representing an equally large number of words from the same author. Such a diagram would then reflect the persistent peculiarities of this author in the use of words of different lengths and might be called the characteristic curve of his composition. Curves similarly formed from *anything that he had ever written* could not differ materially from this." (The italics are mine.) After some preliminary work which seemed to bear out the conclusion ventured above, the writer states: "From the examination thus far made I am convinced that 100,000 words will be *necessary* and sufficient to furnish the characteristic curve of a writer—that is to say, if a curve is constructed from 100,000 words of a writer, taken from *any one of his productions,* then a second curve constructed from another 100,000 words would be practically identical with the first—and that this curve would, in general, differ from that formed in the same way from the composition of another writer, to such an extent that one *could always be distinguished* from the other."

Such is the author's own statement of his theory, which the facts adduced apparently support. The culminating test consisted in the examination of different groups of 100,000 or more words from each of several authors, and it was found that the corresponding graphs did actually coincide. This, in the words of the author, 'must be regarded as convincing evidence of the soundness of the original assumption.'

The existence and uniqueness of characteristic curves being granted, its practical application as a test of disputed authorship is obvious. To quote again, "If it can be proved that the characteristic curve exhibited by an analysis of 'David Copperfield' is identical with that of 'Oliver Twist,' of 'Barnaby Rudge,' of 'Great Expectations,' etc., and that it differs sensibly from that of 'Vanity Fair,' or 'Eugene Aran,' or 'Robinson Crusoe,' or 'Don Quixote,' or anything else, in fact, then the conclusion will be tolerably certain that whenever it appears it means Dickens."

The title of Dr. Mendenhall's second paper, 'A Mechanical Solution of a Literary Problem,' refers to the application of this theory to the Bacon-Shakespeare controversy, which, we are told, formed the objective point of the whole investigation. The characteristic curves resulting from 400,000 words of the plays, and 200,000 words from Bacon's 'Henry VII.,' 'Advancement of Learning' and the 'Essays' were constructed and exhibited together as in Fig. 20. The con-

cluding remark that 'the reader is at liberty to draw any conclusion he pleases from this diagram' only strengthens the impression that the conclusion intended is considered unavoidable, though we are told at the outset that 'the investigation is not to be looked upon as a final solution of the principal problem.'

Considering that it is now over fifteen years since the theory of characteristic curves was first outlined and that no denial of it has appeared, it must be taken for granted that the theory has found general acceptance. It is for this reason that I undertook an investigation, which proved laborious and unattractive in the main, in order to combat with facts an error which to me seemed obvious from the outset. The data which I have now at hand, though necessarily meager, are amply sufficient to establish a duality, if not a multiplicity, of characteristic curves for many authors. But this amounts to a denial of Dr. Mendenhall's major premise, and consequently invalidates his conclusion. Fig. 20, instead of furnishing a convincing proof, or even contributary evidence, leaves the problem of disputed authorship wholly untouched. In fact, my results throw considerable doubt upon the very existence of characteristic curves in the sense that the word has been employed by Dr. Mendenhall. I shall, therefore, use the term *word-curve* when referring to curves representing the relative frequencies of different length words used in composition.

Dr. Mendenhall states that the validity of his method as a test of authorship implies two assumptions: first, that the author makes use of a vocabulary which is peculiar to himself, and the character of which does not change from year to year during his productive period; and second, that in the use of that vocabulary in composition, personal peculiarities in the construction of sentences will, in the long run, recur with such regularity that short words, long words and words of medium length will occur with definite relative frequencies.

These two assumptions are of course independent. Suppose it be granted that authors use vocabularies peculiarly their own. It does not at all follow that these peculiarities will manifest themselves in varying word-lengths. Obviously an indefinite number of different vocabularies is conceivable, each yielding the same average word-length or even fitting to the same word-curve. Now, it is true that if authors are endowed with a word-sense or word-instinct by means of which personal traits are reflected through their vocabularies (first assumption), and if, moreover, this word-sense manifests itself in measurable differences in the relative frequencies of words of a given length (second assumption), then these personal traits or peculiarities of an author will in general modify the contour of the word-curve. But the converse of this by no means follows, that the differences in the con-

tours of word-curves are necessarily due to any personal peculiarities in the respective authors.

The average word-length may be reasonably assumed to depend upon other factors besides the author's word-sense, as the form of composition, the subject matter, etc. A man's gait differs according as he is walking for pleasure or on business, alone or in the company of others, on a long journey or to escape from danger. Similarly the average word-length of the language current in the market place, the street or the drawing-room differs from that employed on the rostrum, in learned discourse or in polite conversation, even though used by the same person. Why should not this difference manifest itself in the written utterances of an author?

Dr. Mendenhall, by an enormous expenditure of labor, attempts to prove his second assumption. How? By taking for granted the converse of the very proposition which he wishes to establish. He actually constructs the word-curves for Mill, Jonson, Dickens, Bacon, Shakespeare and finding that they differ in contour, attributes these differences to personal peculiarities of the respective authors. Not once seems the question to have been raised, much less answered, whether these differences are not due wholly or in part to other determining conditions, such as the form of composition or other accidents.

Now not only can it be shown that the form of composition, at least, is a modifying factor of the word-curve and average word-length, but it appears, indeed, to be the predominating factor, overshadowing all others. Works agreeing in form of composition, though written by different authors, will be found to yield curves more nearly in agreement than different works of widely divergent forms of composition by the same author. Whether or not the author-component in the word-curve can be separated from the others is unknown; certain it is that nothing of the kind has as yet been attempted. With our present knowledge concerning word-curves, conclusions regarding the authorship of spurious or disputed writings based upon a comparison of the word-curves of works differing either in the form of composition or in other essential respects must be considered worthless.

It is not difficult to predict in a general way in what respects word-curves of different types of composition will differ. In the vernacular of a language, so nearly devoid of inflection as our English, three- and four-letter words will naturally predominate. The development of oral speech, following the path of least resistance, will naturally be from the simple to the complex. Combinations of five, six or more letters, representing as many elements of sound, will not generally be resorted to so long as there are abundant simpler combinations, consistent with the possibilities of vocal articulation, to draw from. Now while the possible combinations of two and three letters into words is

inadequate for a civilized language, the possible number of two-, three- and four-letter words, aggregating thousands, is sufficient to supply the majority of words needed for every-day speech. The word-curve of common conversation may therefore be expected to show a maximum ordinate for three or four letters. Words containing five, six or more letters will occur with diminishing frequencies. Few words of more than ten letters will occur. Now this is exactly what takes place. Swift's 'Polite Conversation,' which is a reproduction of the conversation of the uncultured, yields the word-curve shown in Fig. 1. This, after a correction for an excess of seven- and eight-letter words, due to the frequent occurrence of the words ladyship, lordship and certain proper names, is the typical word-curve of extreme light dialogue.

What now will be the probable variations as we pass from this extreme type of composition to other forms of dramatic prose? As conversation becomes more sustained the relative frequency of the personal pronoun 'I' will naturally diminish, the use of prepositional phrases will cause two-letter words to increase, words of six and seven letters will become more numerous at the expense of the frequency of three- and four-letter words. The resulting word-curve must, therefore, cross the former in two places, once between the abscissas one and two, and again near the abscissa five. If we pass from the heavier forms of dramatic prose to narrative, in which dialogue alternates with description and still heavier composition, the personal pronoun will diminish still more in frequency, two-letter words will continue to increase as will also words of six, seven and more letters, and to compensate for this there must be a further decrease in the relative number of three- and four-letter words. This law of change will continue as we pass from fiction to pure description and from the essay style to the opposite extreme of scientific and philosophic discourse. Here the personal pronoun 'I' will have disappeared, leaving the indefinite article 'a' the practically sole representative of one-letter words; with the accumulation of phrases and clauses there is a corresponding accumulation of two-letter prepositions, three- and four-letter words will have reached a minimum to make room for longer derivatives, compounds and technical terms.

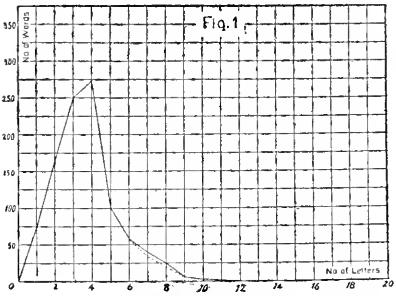

FIG. 1. 5,000 WORD-CURVES FROM SWIFT'S 'POLITE CONVERSATION.' Corrected curve.

Throughout these changes the five-letter word will probably vary least, since the variations on opposite sides of it are in contrary directions. We assume it constant. Taking furthermore Swift's 'Polite

Conversation' and Mill's 'Political Economy' as representatives of the opposite extremes of the chain of forms of composition just described, we have the following schematic types of word-curves (Fig. 2) characteristic not of any particular author, but of the form of composition employed.

Of course no one would expect anything more than an approximate conformation to these types in any specific case, for we have already stated that the form of composition into which an author casts his

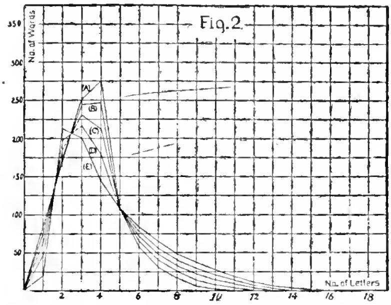

FIG. 2. SCHEMATIC WORD-CURVES REPRESENTING, (*A*) 'Light Conversation,' (*B*) Classic Dramatic Prose, (*C*) Fiction, (*D*) Essay and Description, (*E*) Scientific and Philosophic Discourse.

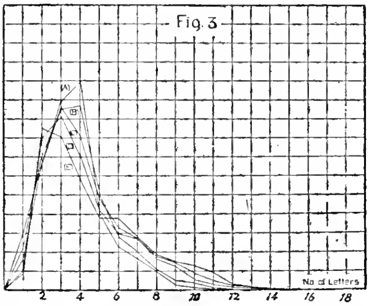

FIG. 3. ACTUAL WORD-CURVES, (*A*) Swift's 'Polite Conversation,' (*B*) Beaumont and Fletcher's Dramatic Works, (*C*) Dickens's 'Christmas Carol,' (*D*) Bacon's 'Essays' and 'New Atlantis' and 'Henry VII.,' (*E*) Mill's 'Political Economy.'

thought is but one of several possible factors affecting the word-curve. But Dr. Mendenhall's diagrams seem to show that it is the predominating factor. In Fig. 3 I have superimposed on one the other four of Mendenhall's diagrams, and to complete the series I have added the word-curve of Swift's 'Polite Conversation.' A more striking corroboration of our hypothesis could scarcely be expected from data intended to establish the theory of characteristic curves.

It may be pointed out in passing that our hypothesis explains several puzzling phenomena brought out in Dr. Mendenhall's investigations. It is now clear why none of the thousand word-graphs from Dickens's 'Oliver Twist' 'could by any possibility be mistaken' for any one of ten similar graphs from Mill's 'Political Economy,' why the 10,000 word-curve from Mill's 'Political Economy' varies very strikingly from a similar curve from his 'Essay on Liberty' (Fig. 4). It explains why the two word-curves of 10,000 words each, one from 'Oliver Twist,' the other from 'Vanity Fair,' agree so closely, fully as closely in fact as two different curves of 10,000 words each from Dickens himself (Fig. 5), an occurrence which Mendenhall remarked, 'must be largely the result of accident, and it would not be likely to repeat itself in another analysis.' Finally our hypothesis removes all

cause for surprise that Shaler's 'Armada Days,' composed 'in the spirit and style of the Elizabethan Age,' should yield a word-curve resembling that of Shakespeare's plays.

Seeing that the assumption that word-curves vary according to the composition employed accounts for nearly everything which had been attributed to personal characteristics of the authors, and that it also explains so much which is inexplicable on the opposite assumption, I

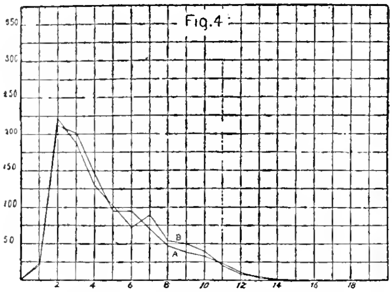

FIG. 4. TWO 5,000 WORD-CURVES (AFTER MENDENHALL) FROM JOHN STUART MILL. (*A*) 'Political Economy,' (*B*) 'Essay on Liberty.'

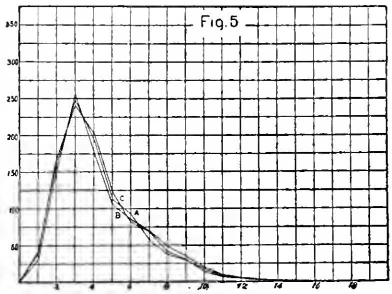

FIG. 5. THREE 10,000 WORD-CURVES OF FICTION (AFTER MENDENHALL). (*A*) Dickens's 'Oliver Twist,' (*B*) Thackeray's 'Vanity Fair,' (*C*) Dickens's 'Christmas Carol.'

sought for a way to test it. But how? According to Dr. Mendenhall, 'no one has written enough in two or three different styles, as prose, poetry, history, essay, drama, etc., to produce normal characteristic diagrams.' This, if true, would exclude any positive test of our hypothesis, but a moment's reflection convinced me that the assumption is entirely unwarranted. Goethe has among his prose works alone, volumes each of drama, biography, fiction, travel, science, criticism and correspondence. Schiller, too, has written far to exceed 100,000 words each of prose, drama and history. And what about Voltaire with his seven volumes of drama, eleven of history, seven of essays, ten of philosophy and eighteen of correspondence, besides several others of poetry, romance, science and commentaries; or George Sand or Lamartine with their libraries of books written in various forms of composition? Our own Dryden, also, has written of essays and prose dramas each more than sufficient to furnish a normal word-curve from each.

Here then was sufficient material to demonstrate the truth or falsity of our hypothesis, if only means could be found to carry out the work. Dr. Mendenhall convinced himself that no less than 100,000 words are necessary to yield an invariable curve, and it would evidently require several such curves to furnish any safe ground for induction. But the examination of several hundred thousand words, allowing but two hours for the tabulation and classification per thousand, would require a greater sacrifice of time than other duties would

permit me to make. Indeed, Dr. Mendenhall found himself in the same predicament, from which he was rescued by the generosity of a private citizen, who supplied the salaries of two assistants for several months during which the necessary data were collected.

Then it occurred to me that though one hundred thousand words may be necessary to yield an invariable curve, a much smaller number might suffice to establish the existence of such a curve within certain limits. If these limits for the curves of different forms of composition from the same author turn out to be mutually exclusive, our hypothesis would be established, though we had not examined a sufficiently large number of words to determine the locus of the curves with accuracy. Thus, possibly, the work necessary to test our hypothesis might reduce itself to manageable proportions.

The first author examined was Goethe. To eliminate as far as possible the disturbing effect of unconscious bias, I decided to count in word-groups of consecutive thousands, always beginning with the first of the work. Quotations, footnotes, headings and, in the case of dramas, stage-directions, etc., were uniformly omitted. These rules were strictly adhered to in all the data which follow. Five groups of one thousand words each were taken from each of Goethe's 'Bürgergeneral,' and 'Literatur Recensionen,' (*B*). The results were tabulated as follows:

TABLE I.

Goethe: 'Bürgergeneral.'

No. of Letters.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Av.
No. of words, 1st 1,000	0	88	331	217	146	91	44	38	19	13	4	5	2	1	1					4.385
" " " 2d "	0	107	326	172	166	79	32	54	24	25	6	2	1	3	1	2				4.498
" " " 3d "	1	91	319	197	136	95	59	32	26	15	12	7	7	1	1		1			4.485
" " " 4th "	1	73	338	204	142	85	53	32	25	16	11	8	3	3	5		1			4.599
" " " 5th "	7	87	324	172	158	93	51	39	22	18	11	4	8	3	1	1	1			4.599
Average 5,000 words.	2	89	328	192	150	89	48	39	23	19	9	5	4	2	2	1	1			4.513

Goethe: 'Literatur Recensionen' (*B*).

No. of Letters.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Av.
No. of words, 1st 1,000		51	268	113	105	122	92	53	65	36	41	21	14	8	5		2	4		5.802
" " " 2d "		48	262	111	131	115	70	66	73	43	32	20	7	11	4	3	1	7		5.792
" " " 3d "		69	261	107	124	112	76	84	61	43	24	17	7	5	7	1	1	1		5.610
" " " 4th "		72	250	109	93	141	87	59	62	57	27	19	10	6	3	3	2			5.716
" " " 5th "		61	251	127	118	111	89	65	67	33	34	10	16	4	2	10	1	1		5.698
Average 5,000 words.		60	258	113	114	120	83	65	66	42	32	17	11	7	4	3	1	3		5.7 23

Each thousand words was now plotted separately and the resulting two sets of five curves compared (Fig. 6 and Fig. 7). These results far exceeded my expectation. No curve of the one set could possibly be mistaken for any curve of the other set. Three-letter words, of which there were between 319 and 338 in each thousand of the first set, were reduced to 250 to 268 per thousand in the second set;

nine-letter words, which did not exceed 26 in any thousand of one, rose to 73 in the other. A similar contrast prevailed in the relative frequencies of four-, seven-, eight- and ten-letter words in the two sets of data. In this case then, at least, five thousand words seemed

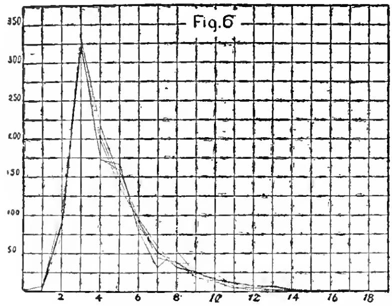

FIG. 6. FIVE 1,000 WORD-CURVES FROM GOETHE'S 'DER BÜRGERGENERAL.' (See Table I.)

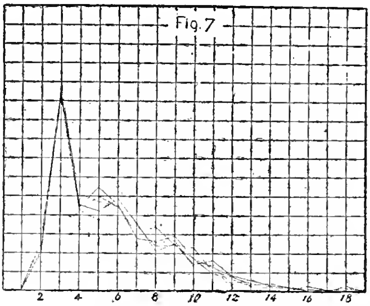

FIG. 7. FIVE 1,000 WORD-CURVES FROM GOETHE'S 'LITERATUR: RECENSIONEN.' (See Table I.)

sufficient to indicate the limits of the invariable curves which a larger number of words would yield, and these limits are actually exclusive except in the proximity of the intersection of the two sets of curves. The normal curve for each group of five thousand words is given in Fig. 8.

Goethe may possibly be exceptional in manifesting such striking uniformity in the curves for successive thousands of the same work, and an equally striking divergence in any two curves belonging to different works. So I turned to Schiller. Ten thousand words were examined, five thousand from his *'Kabale und Liebe,'* a prose drama, and five thousand from his 'History of the Thirty Years' War.'

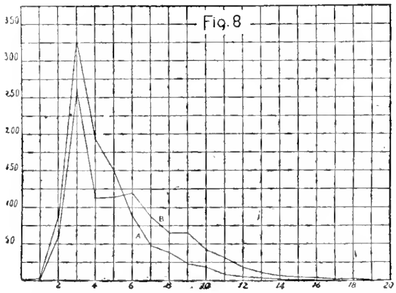

FIG. 8. TWO 5,000 WORD-CURVES FROM GOETHE. (Table I.) (*A*) Prose Drama ('Der Bürgergeneral'), (*B*) Criticism ('Literatur: Recensionen').

A glance at the corresponding word-curves for each thousand words (Figs. 9 and 10) shows that here, too, five thousand words will determine the limits within which the unknown invariable word-curves will be confined with a sufficient definiteness to convince us that the curves can in no wise resemble each other. Four-letter words occur only about half as frequently in the 'History' as in the 'Play'; ten-, eleven-, twelve-letter and longer words are increased two and three-fold.

TABLE II.

Schiller: 'Kabale und Liebe.'

No. of Letters.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	+	Av.
No. of words, 1st 1,000		78	298	203	148	96	54	28	36	19	15	9	7	7	2						4.784
" " " 2d "	2	93	268	209	139	119	55	30	41	14	15	8	2	1	2		1		1		4.738
" " " 3d "	2	82	294	178	139	134	56	47	26	17	14	6	1	2	2						4.978
" " " 4th "		94	277	188	128	107	49	48	37	21	21	10	4	5	1	1	1				4.924
" " " 5th "	2	82	252	195	143	122	55	48	39	18	15	12	8	4	3	1		1			4.291
Average 5,000 words.	1	86	278	195	137	116	54	40	36	19	16	9	4	4	2						4.833

Schiller: 'History of the Thirty Years' War.'

No. of Letters.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	+	Av.
No. of words, 1st 1,000		87	246	103	135	133	65	48	43	33	49	19	13	5	7	6	2		3	2	5.712
" " " 2d "		65	259	96	109	127	86	48	44	51	49	28	11	8	5	5	6	1	1	1	5.937
" " " 3d "		79	256	100	140	86	68	68	63	27	31	27	16	14	7	5	2	8	2		5.878
" " " 4th "		76	256	131	116	115	62	56	41	34	46	23	10	11	6	9	5	2	1		5.745
" " " 5th "		85	232	106	125	117	63	62	53	39	33	34	17	5	9	10	6	2	1	1	5.957
Average 5,000 words.		78	250	107	125	116	69	56	49	37	42	26	13	9	7	7	4	3	1	1	5.846

Fig. 11 gives the word-curves constructed from five thousand averages of the two works.

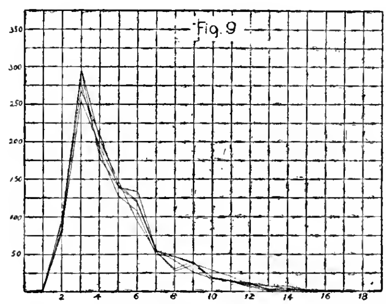

FIG. 9. FIVE 1,000 WORD-CURVES FROM SCHILLER'S 'KABALE UND LIEBE.' (See Table II.)

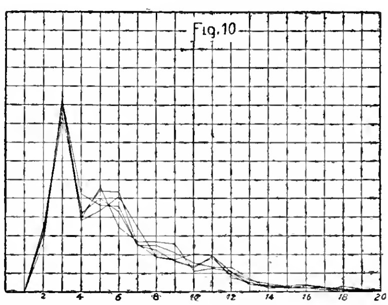

FIG. 10. FIVE 1,000 WORD-CURVES FROM SCHILLER'S 'THIRTY YEARS' WAR.' (See Table II.)

Next I tabulated ten thousand words from Goldsmith, choosing the drama 'She Stoops to Conquer' and his essay on the 'Present State of Polite Learning in Europe.'

TABLE III.

Goldsmith: 'She Stoops to Conquer.'

No. of Letters.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Av.
No. of words, 1st 1,000	76	175	245	185	106	78	57	32	18	14	9	1	3		1	4.021
" " " 2d "	74	216	207	186	96	54	68	44	25	18	6	3	1	1	1	4.052
" " " 3d "	51	197	250	208	89	62	54	27	34	13	10	2	3			4.047
" " " 4th "	64	201	215	220	108	49	67	30	20	14	6	3	2		1	3.997
" " " 5th "	65	217	208	184	92	78	67	37	21	15	9	4	3			4.073
Average 5,000 words.	66	201	225	197	98	64	63	34	24	15	8	3	2		1	4.046

Goldsmith: 'Present State of Polite Learning in Europe.'

No. of Letters.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Av.
No. of words, 1st 1,000	19	231	193	102	87	77	90	74	48	45	25	7	1	1		4.854
" " " 2d "	12	174	207	145	102	94	70	49	53	40	31	18	3	2		5.018
" " " 3d "	16	175	199	148	112	76	62	79	52	42	20	8	10	1		4.985
" " " 4th "	34	183	208	134	116	64	70	55	66	31	18	14	3	4		4.819
" " " 5th "	20	184	178	146	142	95	77	61	39	27	16	10	3	2		4.797
Average 5,000 words.	20	189	197	135	112	81	74	64	52	37	22	11	4	2		4.895

Here the results, graphically exhibited in Figs. 12, 13 and 14 are somewhat less satisfactory than in the case of Schiller or Goethe, yet

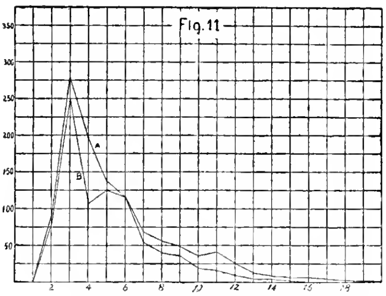

Fig. 11. Two 5,000 Word-curves from Schiller. (Table II.) (*A*) Prose Drama 'Kabale und Liebe,' (*B*) History 'Thirty Years' War.'

even here any one-thousand word-curve of the one work is easily distinguished from all the curves of the other work. The most marked contrast is shown in the relative frequencies of two-, four-, eight-, nine- and ten-letter words.

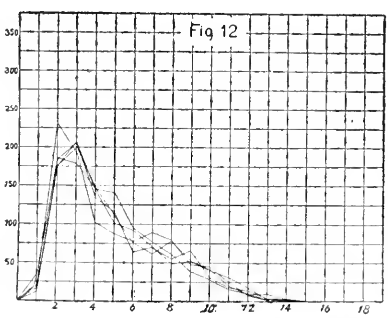

Fig. 12. Five 1,000 Word-curves from Goldsmith's 'She Stoops to Conquer.' (See Table III.)

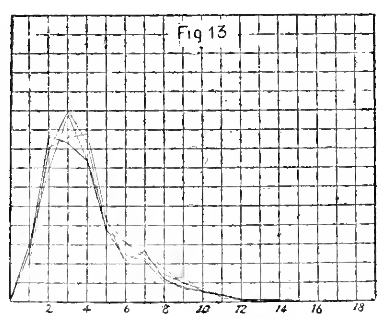

Fig. 13. Five 1,000 Word-curves from Goldsmith's 'Present State of Polite Learning in Europe.' (See Table III.)

On the other hand, Dryden's one-thousand word-curves (Fig. 15 and Fig. 16) appear fully as differentiated as any yet examined. Five thousand words each from 'Sir Martin Mar-all' and the 'Essay on Satire' give:

TABLE IV.

Dryden: 'Sir Martin Mar-all.'

No. of Letters.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Av.
No. of words, 1st 1,000	46	176	263	236	101	69	37	36	25	7	2	1		1		3.910
" " " 2d "	55	181	275	202	98	59	46	33	21	13	8	9				3.995
" " " 3d "	71	189	260	220	114	60	39	28	9	8		1			1	3.724
" " " 4th "	56	174	272	238	104	62	45	25	11	9	3	1				3.813
" " " 5th "	70	184	241	231	93	64	56	31	12	10	6	1			1	3.875
Average 5,000 words.	60	181	262	225	102	63	45	31	16	9	4	3				3.869

Dryden: 'Essay on Satire.'

No. of Letters.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Av.
No. of words, 1st 1,000	30	187	242	184	96	62	72	50	39	17	14	4	1	1	1	4.387
" " " 2d "	36	199	224	186	94	76	75	35	24	26	13	7	3	1	1	4.352
" " " 3d "	38	200	210	183	107	76	71	49	26	22	10	4	2	2		4.346
" " " 4th "	23	192	225	160	111	99	80	56	24	16	5	7	1	1		4.421
" " " 5th "	27	196	228	172	103	90	69	54	26	20	10	1	1	2	1	4.371
Average 5,000 words.	31	195	226	177	102	81	73	49	28	20	10	5	2	1	1	4.375

Here not only are five thousand words sufficient to indicate that the invariable curves for the two kinds of writing differ essentially, but the number of four-letter words alone in any single thousand seems to characterize the drama from the essay.

It seemed hardly necessary to augment these data which may seem to the reader more than adequate to establish the multiplicity of the so-called characteristic curves of an author. Still I ventured another test. Suppose several five-thousand word-curves from different dramatic works of an author were constructed, and again several five-thousand word-curves of various other prose productions as criticism or history by the same author. Suppose it were found that each set of curves agrees in the main, but differ, in essential respects, from all the curves of the other set, could this be interpreted otherwise than that the nature of the composition is the determining factor of the curves? With this thought in mind, I tabulated four additional groups of five thousand words each from Goethe, two groups each taken from single works, the other two groups made up of single thousands from each of ten different productions. These together with the five thousand averages previously obtained from the 'Bürgergeneral' and 'Literatur Recensionen' (B), are given in Table V., and the corresponding word-curves are given in Fig. 18. Fig. 19 shows the two curves which result if the entire fifteen thousand words are taken

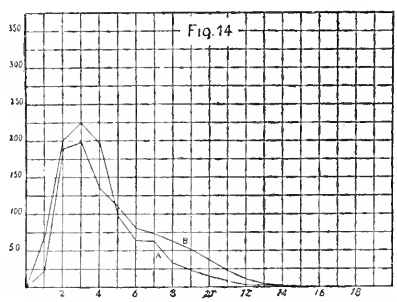

FIG. 14. TWO 5,000 WORD-CURVES FROM GOLDSMITH. (Table III.) (*A*) Drama 'She Stoops to Conquer,' (*B*) Essay 'Present State of Polite Learning in Europe.'

Table V.

Goethe: 'Prose Drama.'

No. of Letters.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	+	Av.
Egmont, 1,000 words.		68	318	201	149	107	47	51	17	20	8	6	2	2	2	2			4.647
Clavigo, " "	1	79	295	202	140	115	48	35	29	25	14	10	1	3		2		1	4.761
Stella, " "	1	86	285	202	140	119	58	46	25	14	12	8	2	2					4.685
T. d. Empfindsamkeit, 1,000 words.	3	78	300	175	143	110	57	52	30	28	14	2	3	2	2				4.780
Die Anfgeregten, 1,000 words.	1	67	325	184	158	101	55	39	23	18	17	4	5	2					4.665
Average, 5,000 words.	1	74	305	193	146	110	53	45	25	21	13	6	3	2	1	1	1		4.708
Gaetz v. B.," "	1	84	315	193	138	113	53	36	25	16	11	8	4	3	1	1	1		4.626
Der Bürgergeneral, 5,000 words.	2	89	328	192	150	89	48	39	23	19	9	5	4	2	2	1	1		4.513
Average, 15,000 words.	1	83	316	193	145	104	51	40	24	19	11	6	4	2	1	1	1		4.616

Goethe: 'Criticism and Description.'

No. of Letters.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	+	Av.
St. Rochus Fest, 1,000 words.		56	267	112	128	108	68	69	61	52	30	24	10	11	1	2		1	5.716
Im Rheingan, " "		58	257	118	122	120	72	49	53	40	38	26	16	14	4	5	5	3	5.877
Köln, " "		80	232	100	91	118	84	70	57	59	44	36	16	8	4	1			5.982
Campagne in F., " "		65	268	110	124	99	63	93	43	40	34	23	15	11	4	5			5.720
It. Reise: Rom, " "		78	266	135	148	110	60	49	42	38	30	23	12	5	2	1	1		5.359
Average, 5,000 words.		67	258	115	123	111	70	66	51	46	35	26	14	10	3	3	1		5.731
Laokoon, Propyläen, " "		70	271	135	113	114	70	68	50	37	29	17	11	7	3	2	2		5.505
Literatur R. (B), " "		60	258	113	114	120	85	65	66	43	32	17	11	7	4	3	1	3	5.727
Average, 15,000 words.		69	262	121	117	115	74	67	56	42	32	20	11	8	4	3	1	1	5.654

as the basis. These will approximately coincide with the invariable curves for the two kinds of composition in question.

Throughout our work we have used the word-curve as the basis of comparison. But the mere fact of divergence of such curves for different forms of composition could have been much more readily estab-

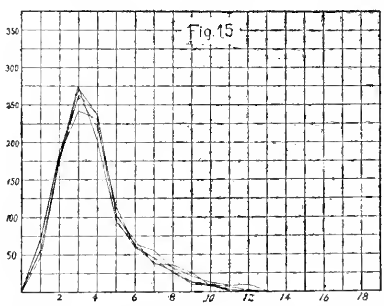

Fig. 15. Five 1,000 Word-curves from Dryden's 'Sir Martin Mar-all.' (See Table IV.

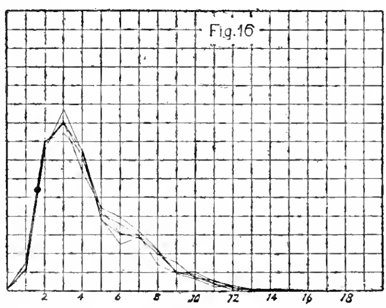

Fig. 16. Five 1,000 Word-curves from Dryden's 'Essay on Satire.' (See Table IV.)

lished by an inspection of the average word-lengths of various works. It will pay to compare carefully the numbers given in the last columns of our tables. None of the averages per thousand in Goethe's prose dramas *exceeds* 4.8 letters per word; in none of his other works examined do the averages *fall below* 5.4. The limits of the average word-lengths for the two forms of composition are thus seen to be not only

exclusive, but they are separated by a wide gap. Goldsmith's averages, 4.0 and 4.9 letters per word, respectively, show a similar difference, and so do Schiller's and Dryden's averages. Doubtless this factor of average word-length alone, which can be determined with an expenditure of but a small fraction of the time required for the de-

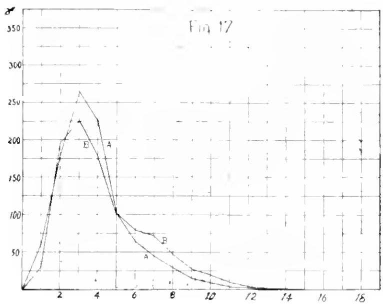

FIG. 17. TWO 5,000 WORD-CURVES FROM DRYDEN. (Table IV.) (*A*) Prose Drama 'Sir Martin Mar-all,' (*B*) Essay 'Essay on Satire.'

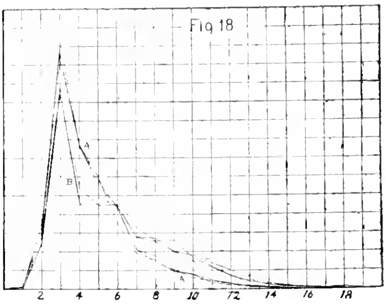

FIG. 18. SIX 5,000 WORD-CURVES FROM DIFFERENT WORKS OF GOETHE. (See Table V.) (*A*) Three dramatic prose curves, (*B*) Three curves of criticism and description.

termination of the figures necessary to construct the word-curves, would in general be indicative of the nature of the curve, so that in critical cases only, the word-curve would need to be examined.

The question still remains whether two word-curves of the same author may vary as much as the word-curves of different authors, that

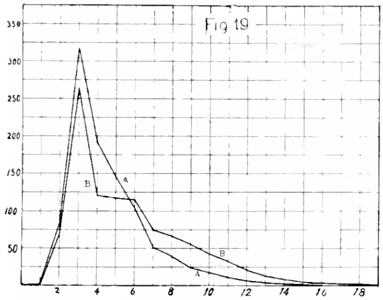

FIG. 19. TWO 15,000 WORD-CURVES FROM GOETHE. (Table V.) (*A*) Dramatic prose, (*B*) Criticism and description.

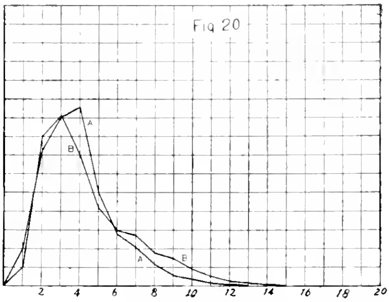

FIG. 20. (*A*) 400,000 Word-curve from Shakespeare; (*B*) 200,000 Word-curve from Bacon. (After Mendenhall.)

is, whether, so far as word-curves indicate anything, an author differs as much from himself as from other authors. This question can not be definitely answered until a large number of authors have been compared, that is, until we have obtained the maximum variation between authors, as well as the maximum variation between various forms of composition. But so far as the evidence at hand may be

trusted, it is to the effect that the line of demarcation follows the form of composition rather than the author. Figs. 11, 14, 17 and 19 show variations that must be attributed to the form of composition; the difference in the curves of Fig. 20 may reasonably be ascribed to the same cause. Fig. 21 shows four five-thousand word-curves, representing two authors and two styles of writing. The curves representing the same style not the same author follow each other. Fig. 22 contains four words-curves of dramas (Shakespeare, Beaumont and Fletcher, Marlowe and Jonson), and four word-curves from the prose writings of Bacon, Dryden, Goldsmith and Mill. While the latter show considerable variations among each other, they are all clearly differentiated from each of the drama curves.

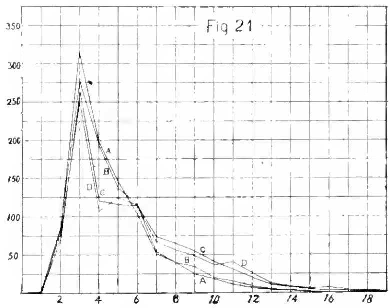

FIG. 21. TWO CURVES EACH OF DRAMATIC PROSE AND DESCRIPTIVE PROSE FROM DIFFERENT AUTHORS. Dramatic Prose, (*A*) Goethe, (*B*) Schiller; Description, (*C*) Goethe, (*D*) Schiller.

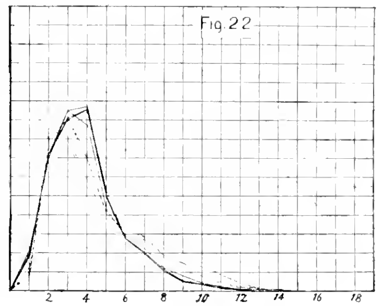

FIG. 22. EIGHT WORD-CURVES FROM ENGLISH WORKS; Dramas (Shakespeare, Beaumont and Fletcher, Marlowe, Jonson), Prose Writings (Bacon, Dryden, Goldsmith, Mill).

The theory of characteristic curves is exactly parallel to that of constant sentence proportions. Both rest upon the same fallacy—that personal peculiarities outweigh all other determining factors to such an extent as to make it unnecessary to consider them. Elsewhere* I have shown that the average sentence length, instead of being invariable for a given author, varies between wider extremes for different styles employed by the same author than for different authors writing in the same style. Goethe alone shows average sentence lengths varying from 5 to 38 words per sentence. Is it not likewise probable that a more extended inquiry would reveal, in the case of versatile writers like Goethe, Voltaire and others, not two only, but a whole series of invariable word-curves, distributed something like the curves in Fig. 2?

It was the theory of spectrum analysis which first suggested to Dr.

* The Sherman principle in rhetoric and its restrictions. POPULAR SCIENCE MONTHLY, October, 1903. On the variation and functional relation of certain sentence constants in standard literature, University (of Nebraska) Studies, July, 1903.

Mendenhall the analogous conception of word-spectra or characteristic curves. Just as the light-rays of various wave-lengths emitted by a substance combine to form its spectrum, so a combination of words of various lengths in proper definite ratios make up an author's word-spectrum or characteristic curve. The analogy is imperfect, but we admit it. But is it true that each substance has a single spectrum? This was the supposition when the science of spectrum analysis was in its infancy, and upon this supposition Dr. Mendenhall bases his analogy. The fact is that over forty years ago it was demonstrated that some substances have several spectra, and to-day it is generally believed that all substances have several spectra, corresponding to the several stages of disassociation or molecular composition of their molecules. The analogy to spectrum analysis, therefore, demands the modification of the theory of characteristic curves, which I have tried to point out in the preceding pages.

THE PHYSIOGRAPHIC CONTROL OF THE CHATTANOOGA CAMPAIGNS OF THE CIVIL WAR.

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AT the opening of the civil war, the leaders of both sides clearly recognized three regions around which important campaigns must center. The confederacy was at a disadvantage in having no marked natural boundaries. The rivers and mountain led *into* rather than *around it*. The territory of the seceding states was roughly divided into three physiographic sections, each of which required a separate force. East of the Appalachians were the Piedmont and coastal plain regions, the struggle for which centered in the vicinity of Richmond. On the west was the Mississippi Valley, the 'gateway to the confederacy.'

The middle section included the rugged portions of Kentucky and Tennessee. By a singular combination of surface features the key to all this area lay in the comparatively small region in the vicinity of Chattanooga. It is the purpose of this paper to trace the relations between the campaigns centering about Chattanooga to the topography of the region—their 'earth control,' as the geographers would say.

"Chattanooga," says Fiske, "was the northern gateway to the center of the confederacy. From it radiated railroads to the Ohio, Mississippi, Gulf and Atlantic; through it were the railroad connections of Virginia with the southwest. Its possession by the federal army would isolate Virginia and North Carolina from the western states of the confederacy, and open a way through Georgia to Atlanta and thence to the coast." On the other hand, its control by the confederates gave them the fertile valleys of east Tennessee and allowed them to threaten Kentucky and western Tennessee. They could readily move troops and supplies between the army in Virginia and the forces in the west. The mountaineers in Kentucky and Tennessee were largely unionists and this provided an additional strong incentive for the federals to control the region.

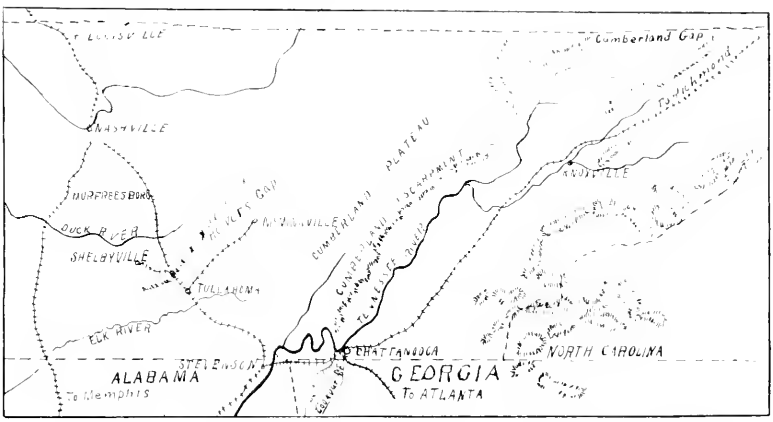
The importance of Chattanooga during the war and the cause of its industrial development since are largely due to physiographic and geological influences. Within a space of a few miles three different geological structures, each having a characteristic physiographic development, approach each other.

Taking these regions in order, the first to the eastward is the Appalachian. It is an apparent jumble of peaks, ranges and valleys, as a glance at the relief map will show. Their ancient crystalline rocks

have weathered with comparative slowness, and consequently the mass stands out in strong relief, extending nearly to the Atlantic and most effectively separating the southern Atlantic seaboard from the interior. So effective a barrier were they that communication from the coastal plain with northern Georgia, Tennessee and Kentucky was either by the passes in Virginia or around the southern end of the mountains by way of Atlanta. Prior to 1880 there was no railroad across these mountains south of Roanoke.

Some of the intermontane valleys are fertile and support a considerable population, but the general inaccessibility of the region is shown by the life and customs of the people, which have scarcely changed since revolutionary times.

In the tilting and folding incident to the formation of the Appalachian system, there was exposed a belt of limestones and shales extend-



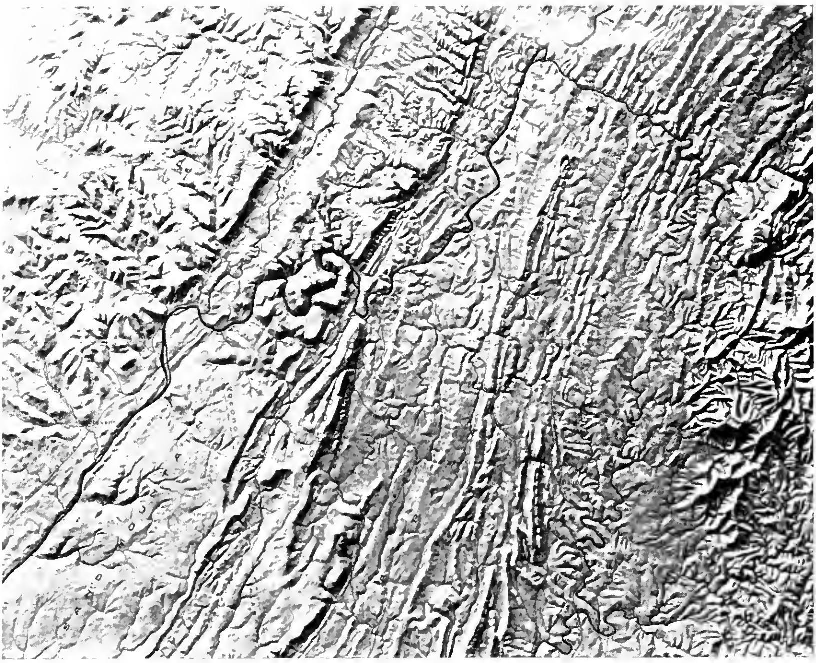
OUTLINE MAP OF THE REGION INCLUDED IN THE CHATTANOOGA CAMPAIGNS.

ing in a direction roughly parallel to the mountain axis. These rocks are tilted and their upturned edges are easily eroded as compared with those on either side. The result of this erosion is an irregular trough from ten to seventy-five miles wide and over a thousand miles long. It is known in general as the 'Great' or Appalachian valley, but has various local names. In New Jersey it is known as the Kittatinny valley; in Pennsylvania it is the Cumberland valley; in Virginia it becomes the Shenandoah valley and in this region, the Tennessee valley or the East Tennessee valley.

The rocks are much inclined and their parallel edges of different degrees of resistance are exposed to the process of denudation, the results of which are long, narrow, parallel ridges running lengthwise along the valley. For example, the famous Chickamauga Ridge is composed of a compact resistant rock, known as Knox dolomite, which stands above the valley floor because the neighboring strata are less resistant to the levelling effects of denudation. The traveler going

through the region is not likely to recognize the valley form, as most of the roads are in smaller valleys between the ridges, but once gain some commanding elevation and the great valley is seen stretching away, its ridges and hills melting into insignificance on its apparently level bottom. The decomposed rock makes a fertile soil which early attracted settlers. From New York to Alabama it is the abode of a prosperous people with well tilled farms and comfortable homes.

Extending westward from the valley is a plateau region which merges on the north and west into the Mississippi valley and is known



Relief Map of the Chattanooga District. (Photographed from model by E. E. Howell.)

as the Cumberland Plateau. The geologist finds no difficulty in accounting for the transition from valley to plateau when the rock arrangement is seen. Here instead of the highly tilted strata of the valley, the rock layers are nearly horizontal. Instead of the troughs and ridges of the valley, the surface, while rough, has an even sky line which tells of a former approximately level surface. The elevations are steep and the streams seem to have no regular arrangement—in short, this region is a 'dissected' plateau. The surface stratum of rock in general is a sandstone which is underlaid by a stratum of more easily soluble limestone. When a stream has cut through the sandstone layer and reaches the limestone, it deepens its valley more rapidly than before and consequently flows in a steep trench.

The overlying sandstone protects the limestone beneath and prevents

its active weathering, thus the rate of recession of a cliff is entirely regulated by the recession of the overcapping stratum. The general result upon the topography is high, cliff-like valley walls, and rather level-topped hills with steep slopes. Where the plateau meets the great valley, this is shown on a grand scale. From Chattanooga northeastward along Walden's ridge for scores of miles stretches a cliff or escarpment which overlooks the valley. It is steep and the streams flowing across the escarpment have gashed it into a serrate profile which gives it the local name of Cumberland Mountain. The lack of roads and general inaccessibility of plateau and escarpment made it a factor to

General view showing one of the Appalachian Valley Ridges in Monroe County, Tenn. (Photographed by the U. S. Bureau of Forestry.)

be reckoned with in the movement of armies. The plateau is heavily timbered and, in contrast with the valley, is difficult of access and sparsely settled. The relief map of the Chattanooga district shows the surface appearance of these divisions.

The drainage of these regions is as peculiar and characteristic as are the surface features. The great valley is a structural valley, and not, as are most valleys, the seat of a great river. Its existence, as has before been noted, is due not to river activity, but to the easy denudation of its rocks as compared with those on either side. The only large

rivers flowing lengthwise of the valley are the Shenandoah and Tennessee. These and the smaller streams have a general direction parallel to the valley trend. They have discovered strata which they can erode and into which they have sunk their channels. The streams on the plateau have no such succeeding parallel strata to guide their course and have cut valleys in an irregular fashion, not unlike the branching of a tree.

Looking at the course of the Tennessee, it would seem that the river could hardly have taken a more roundabout way to the sea. Rising about seventy miles above Chattanooga, it follows the valley trend until it reaches this place. There, instead of continuing about three hundred miles down the valley to the Gulf, the river turns abruptly to the westward and enters the plateau by a deep gorge. Flowing in a meandering course, it passes through northern Alabama and across Tennessee and Kentucky, entering the Ohio River at Paducah, over fifty miles north of its source. It finally reaches the Gulf after a circuitous journey of more than three times the distance that would be required had it taken the course down the valley. Indeed, it is thought that the Tennessee at one time did follow the shorter course, but a tilting of the land together with the rapid erosion eastward of a westward-flowing stream, diverted the river to its present course.

The civil war opened with the Chattanooga region in the hands of the confederates who also controlled Tennessee and Kentucky to the north and west. Both sides were fully alive to the importance of the position and for over two years it was the objective of the union armies. But at this time Chattanooga was nearly one hundred miles within the confederate lines, which reached from Columbus, a strongly fortified post on the Mississippi, to Cumberland Gap, at the northeast corner of Tennessee, where there was a pass to the Great Valley. At about the center of the line were forts Donelson and Henry, which commanded respectively the Cumberland and Tennessee rivers. These rivers were natural roadways into the confederacy, and it was an important step when Grant captured the forts. The first advance toward Chattanooga had been taken, and from now on until its capture Chattanooga was the goal of some union army in Tennessee.

General Rosecrans was in command of the army which found itself ready to start for Chattanooga, with General Bragg as his opponent. Bragg had attempted an invasion of Kentucky, but was checked at the battle of Stone River near Murfreesboro, which left the two armies facing each other on the Cumberland plateau. Rosecrans's army and supplies were concentrated at Murfreesboro and Bragg had his center resting at Tullahoma, a straggling village important only as a railroad junction. The Tullahoma campaign which now followed was indecisive, but is interesting to the student of military history because of the strategy by which Rosecrans forced his adversary to retreat without

incurring serious loss to the federal army. Its consideration is also appropriate in this article, since the plans of the commanders and the movements of their forces were very largely controlled by the physiography of the plateau.

So deeply dissected is this plateau that, without exception, military writers speak of it as the Cumberland 'Mountains.' Weathering and stream work, continued through untold ages, have cut deep valleys and carved hills until we have the present rough country to cross which, even without an enemy in front, was no small undertaking. The soil, derived from Carboniferous sandstone in general is a thin sandy loam,

VIEW IN THE DISSECTED CUMBERLAND PLATEAU, NEAR SEWANEE, TENN. The Mountains are formed by denudation, leaving an even sky-line. (Photographed by the U. S. Bureau of Forestry.)

and only in the valley bottoms where the streams have worn a trench and partly filled it with alluvial sediment is the soil fairly fertile.

The plateau descends towards the plains of middle Tennessee by three great irregular terraces each roughly about five hundred feet high. Through these terraces streams have carved narrow valleys through which the roads pass to the lowlands. These gorges, called 'gaps' by the mountaineers, were as important to the armies in that section as were the 'wind gaps' between Virginia and the Shenandoah valley to the confederates. They were easy to hold with a small force against a numerous body of the enemy and were especially serviceable to a retreating army, since a small rear guard was able to give complete protection.

The question of railroad transportation was an almost paramount one in these campaigns and, as we have seen, was one of the reasons for the military importance of Chattanooga. The modern army with its concentration of men and horses is rarely able to live on the country through which it passes, especially if it is on an offensive campaign and traversing territory through which the enemy has passed. To do so would involve the spreading of the troops over a large area or detaching a considerable force to forage. Sherman's famous march to the sea was a successful instance of a large army living on the country, but he had no active enemy in his front and was passing through the 'garden of the confederacy.' If a railroad or river is not available for transporting supplies, resort must be had to wagon trains.

The average army wagon was drawn by six mules and carried a day's rations for five hundred men. If the distance were such that the wagon could not make a complete trip in one day, more wagons were required. It was even harder to provide food for the horses. When cattle could be driven it would give some relief to the wagon trains. To give a general idea of the magnitude of this work, it is estimated that it required one thousand wagons and six thousand horses to feed an army of fifty thousand men when they left the railroad or base of supplies for a distance of two days' march. This estimate assumes good roads and no breakdowns or stoppages by the enemy and does not include transporting the sick and wounded or the ammunition and materials of war.

The Louisville and Nashville railroad winds through the plateau following the valleys which the streams have cut. It crosses many streams and deep gorges by wooden bridges which were easy to destroy and difficult to rebuild. Both armies were dependent on this road for their supplies. About Tullahoma the soil, before it was cleared, supported a growth of pines and from the general inhospitality of the region was known as the 'Pine Barrens.' The soil drainage was so easy that in a dry summer there was scarcity of water on the uplands, but in a rain, as one of the federal officers complains, 'The soil became as quicksand after a rain, allowing artillery and wagons to sink to the hub.' Thus the dependence of the two armies upon the same line of railroad was almost absolute.

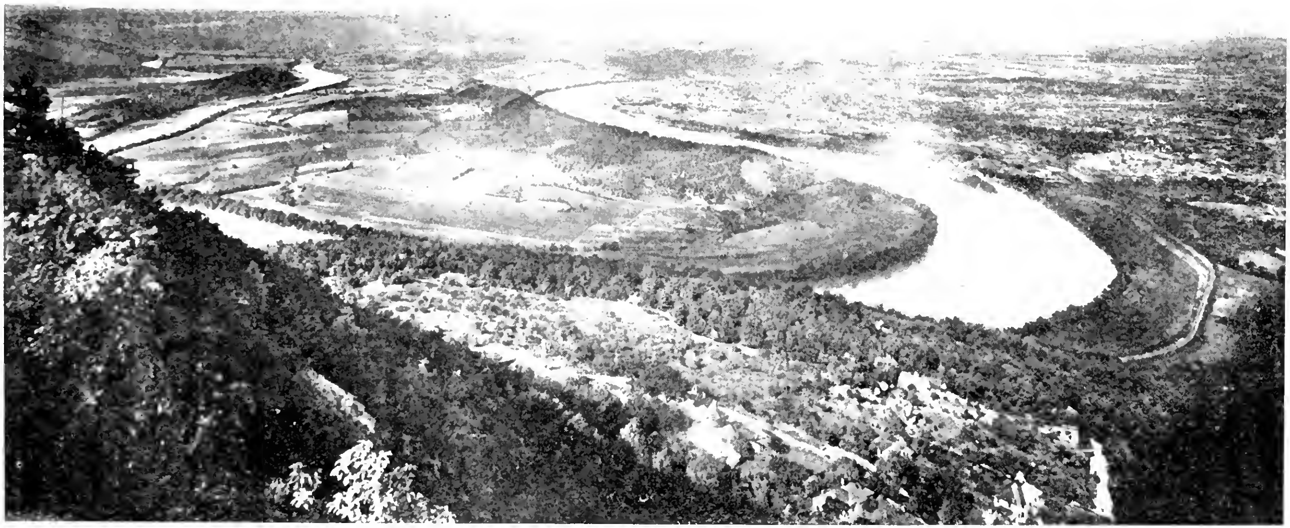
After the battle of Murfreesboro, Bragg's policy was one of defense. His position was strong and well taken. His center and depot of supplies was at Tullahoma, where he had thrown up extensive intrenchments. His left was at Shelbyville, about thirty miles to the northwest in the Duck River valley. This town was in a fairly fertile alluvial valley which offered some sustenance for the troops and horses and, further, was a center from which roads diverged in all directions. Moreover, if he were forced from his position, he could retreat to the plateau which could be fairly easily defended. To his right from Tul-

lahoma, Bragg had posted bodies of troops for the double purpose of defense and of threatening the union base at Murfreesboro. Bragg believed that he had sufficient men in this vicinity to guard the narrow defiles through which most of the roads ran.

Without going into detailed accounts of movements of troops, Rosecrans's plan may be briefly stated. Realizing the strength of Bragg's left at Shelbyville, the union general resolved to attempt what his opponent evidently considered well-nigh impossible—to get his forces on Bragg's right in such a position as to threaten the latter's line of communication and compel him to evacuate his strong position.

THE TENNESSEE BREAKING BY A STEEP GORGE THROUGH THE 'MOUNTAINS.' Owing to the swift current it is there called the 'Suck.'

A strong union force with several days' rations in wagons and *on hoof* was detached for this movement. A vigorous attack on Bragg's left partly concealed the plan of Rosecrans and prevented him from sending reinforcements from here. The movement was successful and the defiles or 'gaps' were secured by which the troops could pass to the level of the plateau on which Tullahoma was situated. The confederate general, not waiting for his line of supplies to be destroyed, retired to the Tennessee, burning the bridges and destroying the railroad as he went. A pursuit was attempted which was entirely ineffectual. The passage of the confederate army had left the roads almost impassable and their rear guard had little trouble in defending the defiles through which their columns had passed. Bragg crossed the Tennessee and leisurely led his army into Chattanooga.



Moccasin Bend from Lookout Mountain. Chattanooga is seen in the middle ground. The long even sky-line to the left is the plateau escarpment. The small plateau on which the battle of Lookout Mountain occurred is in the immediate foreground.

At this stage the immediate topography of Chattanooga and its vicinity became important in determining the military movements. Looking at the relief map it will be seen that the city lies at the western side of the great valley close to where the river breaks into the plateau. It winds through Sand Mountain in a deep gorge which narrows in places, making the current so swift that an ordinary steamboat could not ascend without aid from teams or men on the shore. When the river reaches a long, narrow trough, called the Sequatchie valley, it takes this easier path and flows sixty miles before again crossing the plateau in its indirect course to the Ohio. Near the city the river flows to Lookout Mountain and then doubles on itself, flowing northwesterly,

LOOKOUT MOUNTAIN FROM THE BANK OF THE TENNESSEE RIVER. Hooker's forces ascended the north slope and the battle took place on a small plateau or shelf, seen about half way up the mountain.

almost parallel to its course, for several miles. This is the famous Moccasin bend, so called, of course, from its rough resemblance to an Indian's moccasin. At the apex of the bend towers Lookout Mountain, the most conspicuous feature of the vicinity. Geologically it is a part of the plateau from which it is separated by a narrow erosion valley. It is capped by a sandstone stratum which slopes to the south, where it finally merges into the general level in Alabama. Its bold profile against the sky at once attracts the eye, and the name is decidedly appropriate, since on a clear day several states can be seen from the summit. The ridge, for so it must be called instead of 'mountain,'

rises in slopes so steep that they were insurmountable by an army, until its summit is fourteen hundred feet above the rapid current. A mile or so eastward is Missionary Ridge, roughly parallel to Lookout, but much lower and more accessible. Its top is really a succession of hills or knobs. Between these ridges is Chattanooga Creek, which enters the Tennessee near Chattanooga. Still to the eastward of Missionary Ridge is the famous Chickamauga Creek. Looking westward from Lookout summit, the view is wild and picturesque in the extreme. Extending to the base of the mountain the valley of Lookout Creek is seen in the immediate foreground. Beyond that is the rough Sand Mountain, whose name tells the story of its rock structure and suggests its scraggly covering of trees and shrubs. To the northwest the river winds in its narrow gorge in the plateau for a few miles and disappears around Sand Mountain. North of the river Sand Mountain is continued and known as Walden's Ridge.

Returning to the military movements, we find Rosecrans on the Cumberland plateau, in the vicinity of McMinnville. For some time he was busy repairing the seventy miles of railroad leading from Murfreesboro towards Chattanooga, which the confederates had destroyed in their movement southward. Some of the bridges of this road were destroyed and rebuilt four times in the course of the war. The Chattanooga and Nashville railroad passed to Stevenson, a small town about thirty miles down the river from Chattanooga, where it joined the railroad leading from Chattanooga to Memphis on the Mississippi. Stevenson was the federal base of supplies. The road then crosses the river at Bridgeport, crosses through a ravine, a spur of Sand Mountain into Lookout Valley, and thence passes around the northern end of Lookout Mountain into Chattanooga. To protect this line Rosecrans was obliged to detail thousands of his troops; each bridge was guarded by a detachment of soldiers who generally had built a stockade in the vicinity. The country was swarming with detached bands of hostile 'guerrillas' who would wreck a train or burn a bridge and then escape.

The union commander had open to him two approaches to Chattanooga. He could advance over Walden's Ridge directly upon the city, but this route was beset with difficulties. The roads were very poor and led over the hilly, wooded plateau. After a rain they speedily became impassable to wagons. His base of supplies and nearest railroad point was at Stevenson, from which he would be compelled to haul supplies for the army in the presence of an enemy well supplied with cavalry; moreover, he would have to cross the river in boats at Chattanooga in the face of a vigilant foe. In spite of its difficulties this was the way which Rosecrans was generally expected to take, as it was thought that Burnside, who was near Knoxville, up the valley, would come down and join in the movement.

The other approach lay along the river valley and across Sand Mountain. The advantage of this route was that the army was near its base of supplies, with which it had both river and railroad connection. However, the roads were poor and the route lay across parallel ridges, almost inaccessible except in a few places. It would be hard to maintain a compact advance over the rough country, and a regiment of the enemy could easily delay an army. Rosecrans chose this route and the manner in which he maneuvered his army was certainly a brilliant piece of strategy.

Bragg had expected the federal army to come over Walden's Ridge, and Rosecrans did all in his power to strengthen that belief. Troops were deployed in front of Chattanooga and at night camp fires were lighted on the hills above the river. By feinting in this way Rosecrans was able to advance his army into Lookout Valley without encountering opposition. From here he went through the passes of Lookout Mountain into Chattanooga Valley and threatened Bragg's line of communication with the south. Bragg led his army out and, after a series of maneuvers, the battle of Chickamauga was fought with disastrous results to the federals. Had it not been for the stand made by Thomas, the 'Rock of Chickamauga,' the union army would have been routed. As it was, they were driven into Chattanooga and imprisoned by a seemingly impregnable line of works. Lookout Mountain was abandoned and at once occupied by the confederates. It was apparently the key to the situation.

Rosecrans had caught the wolf by the ears. He had gained Chattanooga, but was a prisoner in its outworks. To advance against the strongly entrenched enemy was folly. To retreat across the plateau would have demoralized his army besides losing the position he had won at such cost. Worst of all, the enemy had taken possession of Lookout Mountain, which Rosecrans had felt obliged to abandon. They had fortified the position and placed guns which commanded the river and railroad west of Chattanooga, thus cutting off supplies from that direction. For awhile provisions came over the Cumberland plateau, but the hardships of the route soon exhausted the teams which could not follow the river, as that was patrolled by the enemy's pickets and were obliged to take circuitous roads over the hills and away from the river. The cattle that were driven that way were hardly able to stand alone, much less furnish sustenance. The soldiers with grim humor spoke of them as 'dried beef on the hoof.' Bragg, confident of his game, sat down and waited for the union army to be starved into surrendering, and his hopes did not seem unreasonable.

The north was thoroughly alarmed at this state of affairs and Grant was put in command. His first work was to open a line by which supplies could reach the city. The celerity with which he accomplished this makes one wonder why it was not done before. The only feasible

route was up the river, but the works on Lookout Mountain controlled both the river and the railroad west of the town. Down the river and out of range of the guns on Lookout was Brown's ferry, which was guarded by a force of confederates. Hooker's division, which had been brought from the east, was thrown across the river and, capturing the force there, entrenched a position commanding the river, which was now clear below this point.

The famine in Chattanooga soon ended. Supplies came to Bridgeport, from thence to Brown's ferry, which Hooker was guarding, and then by wagon to the army. The soldiers were soon well fed and clothed by the 'cracker route,' as it was appropriately called.

Grant was now free to develop offensive plans. It will be remembered that Bragg's lines stretched from his left on Lookout Mountain to Missionary Ridge, where his right was strongly entrenched; Thomas was to threaten the confederate center, Sherman was to attack heavily on Missionary Ridge and Hooker was to move on Lookout Mountain and the enemy's left.

The latter's movement in the celebrated 'battle above the clouds' was successful. However, since the establishment of the new line of supplies, Lookout had ceased to be the key to the position. Sherman found the opposing works stronger than he expected and he was not immediately successful. However, in the center the unexpected happened. This position was believed to be too strong to be carried by direct assault and the attack was intended to prevent reinforcements being sent against Sherman. The troops had orders to stop at the first rifle pits, but they could not be restrained. They rushed up the steep slope, carried the position and the confederate center was broken. Bragg was badly beaten and withdrew to Dalton. The region was not out of union hands during the rest of the war.

Chattanooga's importance has not ceased with the close of the war. Its position at the gateway between the grain and cotton states, together with the resources of the surrounding country, makes the location of an important city in this region almost inevitable. Since the war, the river has been made navigable most of the year to the Ohio. Railroads have multiplied and eleven lines enter the city. Iron, coal, limestone, cotton, lumber, grain are near at hand in the valley and plateau. The city's population and manufactories have doubled in a few years. The battlefields in the vicinity have been surveyed and mapped and the Chattanooga and Chickamauga parks rank with Gettysburg among the military parks of the world.

At a point near Chattanooga one can view the two aspects of the place without changing his position. In the beautiful national cemetery rest over twelve thousand veterans of '63. Turning a little, the city is in view. Its factories are a prophecy not only of the city, but as well of the New South.

THE VALUE OF TEETH AS A MEANS OF IDENTIFICATION.

By ALTON HOWARD THOMPSON, D.D.S.,

PROFESSOR OF COMPARATIVE ODONTOGRAPHY, KANSAS CITY DENTAL COLLEGE.

I HAVE been reminded by the articles in the POPULAR SCIENCE MONTHLY, of the neglect of the teeth as a means of identification, which to me, as a practical dentist, has always seemed very remarkable. No system of identification that I am aware of has ever mentioned these valuable organs for this purpose, notwithstanding the facts that they are so varied in features and are so durable. They are the most indestructible of all animal tissues and their value in this respect ought to be appreciated, for after death, when all the other tissues have disappeared, the teeth remain and maintain the features and peculiarities that they presented in life. It is a source of wonder to the dental profession that the signs furnished by the teeth have been so persistently overlooked in systems of identification, especially by life-insurance companies. The number of signs furnished by the teeth, both of natural features and of artificial operations upon them, is so varied and extensive that they present an amount of valuable data that ought not to be ignored.

A simple system of record of the natural peculiarities of the teeth and of the artificial operations upon them could be devised which in the hands of a competent person, who would need to be an expert dentist, of course, would furnish reliable and less perishable evidence than the other external signs of the body. Every dentist keeps a record of all the operations he performs for every patient, upon an individual chart or page in a special diagram, for his own convenience and protection. By means of these charts, dentists have, in several instances, assisted materially in the identification of the bodies of persons for whom they have operated, after catastrophes, notably the charity bazaar fire in Paris. A similar chart could be incorporated in the examination records of life insurance companies, for instance, on which the dental peculiarities could be recorded in a manner which could be easily read by another expert. Even if some teeth were lost or altered in the course of years, many signs would yet remain on the surviving teeth, for the original form of a tooth would be the same and an artificial operation could not be obliterated. Thus the size and width of the arch; the size, shape and color of the teeth; teeth missing

or altered; kind of fillings and location; gold crowns, bridges or artificial plates, etc. All these and other distinct features could be easily recorded with sufficient clearness to enable the record to be compared with the subject, even if dead and if only the skeleton remained, to assist materially in identification by another expert.

By way of suggesting a scheme for the tabulating of the dental peculiarities, the following plan of classification is proposed, which covers all the general features of the teeth and their environments and could be recorded by one and read by another expert dentist. This scheme is merely suggestive and could be improved by practise and experience.

Classified list of dental and oral peculiarities:

(*a*) Curve of arch, whether round, square or V-shape.

(*b*) Width of arch, in centimeters—from outside surfaces of first upper molars.

(*c*) Depth of vault, from grinding faces of molars.

(*d*) Color and texture of gums, peculiarities of ridges in roof.

(*e*) Size of teeth, whether large small or medium.

(*f*) Shape of teeth, whether wide or narrow, long or short, worn or not, etc.

(*g*) Color of teeth, white or dark, yellowish, bluish or modifications, etc. (This factor would be modified by time and habits, but the expert observer would estimate that.)

(*h*) Irregularities of the teeth, as to being out of normal place, crowding and malpositions generally.

(*i*) Teeth absent totally.

(*j*) Fillings in teeth—noting positions on crown and materials employed.

(*k*) Cavities of decay unfilled.

(*l*) Diseased teeth, dead teeth, chronic abscess, etc.

(*m*) Artificial teeth crowns—porcelain, gold, bridge teeth, etc.

(*n*) Artificial teeth on plates.

(*o*) Miscellaneous peculiarities—such as abrasion, pits or other congenital markings; lingual cingules; number of cusps on second lower bicuspids, upper second molars, etc.; third molars, whether present or absent; forms of crowns, etc., and all abnormal forms of teeth, etc.

Many of these characteristics might be perishable, of course, and of value only for a limited time, but others are of permanent durability and would last while the teeth themselves lasted. The perishable data would need to be taken into consideration at a later examination and a practical dentist would naturally make such allowances. The absence of some data would not always mean lack of identity, for a reasonable allowance would need to be made for perishable dental features.

A chart is shown as an example on which is recorded some of the peculiarities of an ordinary mouth according to this scheme. (Fig. 1) (*a*) Round square. (*b*) 5.8 cm. (*c*) 2.5 cm. (*d*) Gum reddish-pink; health line well marked; rugæ shallow and rather straight. (*e*) Medium small. (*f*) Rather wide and short, cusps low and rounded.

(*g*) Rich cream color shading to yellowish at cervical border. (*h*) Upper laterals both everted at mesial border: right lower central crowded inward. (*i*) First right upper bicuspid and second left lower molar missing; first upper molar broken off and roots remaining. (*j*) 1, gold filling; 2, large amalgam filling; 3, cement filling. (*k*) 1, deep decay; 2, shallow decay. (*l*) Dead tooth and chronic abscess and fistula. (*m*) 1, gold teeth crown; 2, porcelain crown. (*n*) 1, third molar peg-shaped; 2, both lower bicuspids of tricuspid form; 3, whitish spot on labial face.

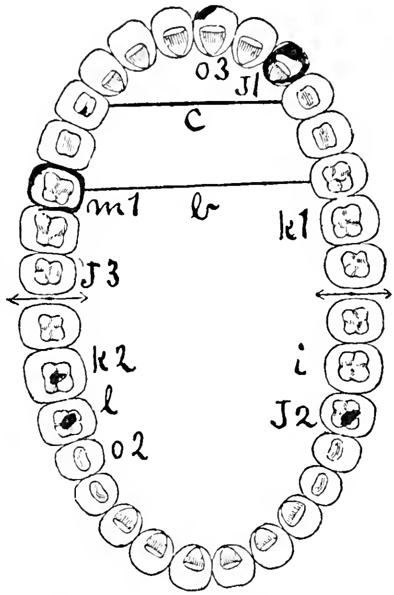


FIG. 1. UPPER JAW ABOVE; LOWER JAW BELOW.

The history of life insurance litigation demonstrates the value of imperishable physical data for the purpose of identification, and these data the teeth furnish. It is more than probable that much expensive litigation and unfair decisions would have been avoided if these data had been heretofore utilized. In the celebrated Hillmon case, which dragged its slow length for twenty years through the United States courts of the west, casts of the alleged corpse of Hillmon were placed in evidence which showed that the denture was perfect and regular, while the teeth of Hillmon himself were said to be irregular and some were absent. It was a case in which the body was so disfigured by decomposition that evidence in regard to the teeth was of the utmost importance. If a chart of Hillmon's own teeth could have been produced which showed some of his dental peculiarities (missing teeth, irregularities, fillings, etc.) a comparison with the teeth of the corpse would have been of advantage so that the case would have been sooner settled and much tedious and expensive litigation avoided.

The data are so accessible and so important, that we feel justified in urging the matter upon the attention of those who have charge of the classes of which physical records are required. The dental data should be employed as supplementary to other systems of signs for identification, and would thus be of value in the records of soldiers and criminals as well as for insurance companies.

IMMIGRATION.*

By Dr. ALLAN McLAUGHLIN,

U. S. PUBLIC HEALTH AND MARINE HOSPITAL SERVICE.

CAUSES of emigration may be considered according to their origin, and divided into three classes. (1) Individual—the spontaneous desires for better things arising in the emigrant himself; (2) local—existing conditions surrounding him in his old world home which develop and stimulate his inherent desire for social, political or financial betterment; (3) extraneous—outside influences operating from America or other countries.

In considering the causes arising within the emigrant himself—the desire for ownership of a home will be found present in a very large proportion of cases. This desire for his own home probably exists in the heart of every man worthy of the name. It forms the foundation of our social structure and is the unit of civilization and advancement among all progressive races. In the early days of the republic it is certain that the immigrant was a homeseeker in nearly every instance, like his predecessor the colonist. And probably this desire to become owners actuates the majority of immigrants, even in our own day.

Often coupled with the desire for ownership of a home there exists in the independent liberty-loving immigrant a desire for free institutions, for a country where the schools are open to all regardless of race or creed, where he may worship God in his own way, according to the faith of his fathers, and where in time he may through the franchise play at least a small part in the political life of his adopted country.

The emigrant leaves often to escape compulsory military service in support of a government in which he has little or no representation. Thousands of European immigrants who arrived in the United States just previous to or during the civil war left Europe rather than submit to compulsory military service, and yet voluntarily enlisted and served faithfully in the union armies in the great conflict. They showed that they were not afraid to fight when the cause at issue was in accord with their principles, but that they resented the military system of their native land.

* Dr. Allan McLaughlin, of the Bureau of Public Health and Marine Hospital Service, of the Treasury Department, has contributed to The Popular Science Monthly several articles on 'Immigration,' which have been of much interest to readers and have been highly commended by experts. We are pleased to state that Dr. McLaughlin has consented to continue this series of articles, covering in a systematic way the whole problem of immigration.—Editor.

And then there is the restless emigrant who desires simply to better his financial condition. He recognizes no patriotic obligation to the new country which treats him kindly, and has no quarrel with the country of his birth, but intends returning to his native land when he has acquired a competence in the United States.

Many of the existing conditions in Europe act strongly as contributing causes of emigration—the price of land in many countries is prohibitive, especially when the poverty of the mass of the people is considered. In other countries, systems of land tenure obtain which make it impossible for the tenant to become an owner.

In parts of Europe discrimination against certain races or religions is carried to the extent of debarring any one of the proscribed race or religion from owning land. This same discrimination against race or religion imposes educational barriers in some countries which prevent the elevation of the poor because of their race or religion in the social scale.

Many emigrants, therefore, leave Europe because they know that in the United States their children will enjoy educational advantages denied them at home, and without which they can not hope to better their condition.

Great density of population and the accompanying excessive competition in the struggle for existence explain emigration from some parts of Europe, and emigration is further stimulated in many of these congested areas by the pressure of militarism.

When some of the contributing causes originating in Europe are accentuated, when militarism exists with its concomitant evils of grinding taxation and compulsory military service, when persecution and over-crowding make the struggle for existence hopeless, emigration becomes the alternative of starvation, and the instinct of self-preservation forces these unfortunate creatures to flee at the first opportunity to some new country.

Convicts, paupers, cripples and diseased persons have many times been shipped to America 'to be rid of them,' by individuals, societies, municipal corporations or even by government agents.

Of the third class of extraneous causes operating from America or other countries, the most important is the prosperity of the United States.

During periods of great prosperity the wave of immigration attains its greatest height, and reaches its lowest ebb during periods of industrial and commercial depression. Thus during 1882 and 1903, the total of our immigration reached its maximum, while following 1873 and 1893 a rapid falling off is noticeable. The people in Europe are informed of our wonderful industrial growth and general prosperity by letters from friends and relatives in this country. These letters contrast conditions of life in America with the poverty or oppression of the

old world, and often contain considerable sums of money, which is convincing evidence to the European peasant. During periods of depression the tone of the letters reflects the change of circumstances and letters are less likely to contain cash remittances. According to statements of steamship officials, from 40 to 55 per cent. of our immigrants come here on tickets prepaid by friends in the United States—so that the successful immigrant here is the best advertisement of the advantages afforded by the United States, and one of the greatest factors in inducing immigration.

There is no doubt that in the past large employers of labor encouraged emigration from Europe, but there is no longer any necessity for them to induce emigration, either by agents or by advertisement, and the practise has almost ceased.

The transatlantic steamship companies have found the business of transporting immigrants to America very profitable and have done much to develop our immigration to its present mammoth proportions. Although the steamship companies deny the fact, a well organized system undoubtedly exists in Europe, by means of which agents and sub-agents of the steamship companies induce emigration. The companies do not openly countenance the system of misrepresentation which the sub-agents employ, but the fact remains that it is in their power to remedy this evil, which they still permit to be practised. For the sake of the commission allowed them these sub-agents picture America as an El Dorado to the peasants, telling them that passage to America is the certain road to fortune.

One of the most potent causes of emigration from Europe is the assistance given the poor of certain races by rich individuals or philanthropic associations. Thousands of Roumanian and Russian Jews, forced by persecution to emigrate, are assisted by the Jewish societies or individuals in the towns through which they pass and are thus helped to the seaboard. Many are passed on through Hamburg, Rotterdam, Libau or some other continental port to London. Here they are met by the representative of the 'Hebrew Shelter.' This institution was founded in 1885, for providing a temporary refuge, and to assist Hebrews *en route* to America. The Jewish Board of Guardians was founded in London in 1859. According to the report of the British royal commission on alien immigration the policy of this Jewish Board of Guardians is to lessen the pressure of alien immigration upon England.

They persuade undesirables of their own race by circulars issued abroad, to embark for other countries than England, and if such undesirable persons arrive in England, render them assistance, and help them to emigrate to other countries. The majority of the undesirable Jews, thus persuaded and assisted, eventually land in New York. They are a hopeless, poverty-stricken people, fleeing anywhere, without object

other than to escape persecution in Russia or Roumania. When they finally reach New York, so complete is their pauperization, that they require assistance, in many instances for years after landing.

Thus the causes of emigration will be seen to indicate in most cases the relative desirability of emigrants. The best are likely to be found among those whose emigration is voluntary or spontaneous, and the worst are likely to be found among those assisted and pauperized by societies or rich individuals, while between the two extremes the others can be graded in varying degrees of desirability.

The first legislation relating to immigrants bears the date of March 2, 1819. A clause in this act provided for the enumeration upon arrival, as well as a statement of the age, sex and place of birth of immigrants. This provision of the law was expected to regulate the transportation of immigrants, to prevent overcrowding on the ships and to mitigate some other abuses on shipboard. Laws for regulation or restriction of immigration have always been the result of popular demand, and have been enacted from time to time either to correct existing abuses or to prevent the entrance of certain undesirable classes. The fact, therefore, that no immigration legislation was enacted from 1819 to 1875 speaks well for the immigrants arriving during that period.

It must not be supposed that the coming of immigrants was entirely unopposed during this period, but the clamor raised against them about 1850 was based on racial or religious grounds, was sectional, not general, and so manifestly selfish and bigoted that the great majority of Americans took no part in it, and no restrictive legislation resulted. About 1875 it became evident that some regulation of immigration was necessary in order to prevent certain undesirable classes, regardless of race, from landing. As a result the act of March 3, 1875, was recorded in the statutes. The classes barred by this act were prostitutes and convicted felons. By 1882 other undesirable classes attracted attention, and a law passed in that year added to the list of excluded classes, all idiots, lunatics, and 'persons unable to care for themselves without becoming a public charge.' It also provided that a head tax of fifty cents be collected from each arriving alien, the money to be paid into the treasury of the United States and to constitute the 'Immigrant Fund.' This fund was to be used in defraying the expenses incident to the regulation of immigration.

Previous to 1885, large employers of labor imported workmen under contract for less than the American standard of wages, and through the combined efforts of the labor organizations, legislation was enacted in 1885 to prevent the entrance of these contract laborers.

The first contract labor act of 1885 was strengthened by the amendatory act of 1887, by which power to make regulations and rules and issue instructions, not inconsistent with law, for the carrying out of the provisions of the act, was vested in the Secretary of the Treasury.

Up to this time the inspection of immigrants was made by state authorities, acting, of course, under federal law. This system was unsatisfactory, because of the lack of uniformity of inspection, and the difficulty of applying the law in imposing and collecting fines. It became evident that if an efficient uniform standard of inspection was to be established and maintained, it must be under the direct supervision of the federal authorities. The act of March 3, 1891, besides adding to the excluded classes, 'persons suffering from a loathsome or a dangerous contagious disease,' polygamists, and assisted immigrants, provided for the assumption of the work of inspecting immigrants by the federal officers. The office of superintendent of immigration was created, and the President was authorized to appoint such officer by and with the advice and consent of the Senate. The medical inspection was from this time to be made by officers of the Marine Hospital Service. This act also prohibited steamship companies from encouraging immigration by alluring advertisements, and provided for the deportation, within one year after landing, of any alien landed in the United States in violation of law.

The act of March 3, 1893, provided that the steamship companies should furnish lists or manifests made at the time and place of embarkation, which were to contain valuable information concerning the age, occupation, destination, moral and physical fitness, etc., of the immigrant. These lists were to be signed and sworn to by the master and surgeon of the vessel. This requirement of manifests was expected to cause a more careful scrutiny of passengers at the port of embarkation, and the manifests themselves would undoubtedly prove of great value to the inspectors in their work.

Under federal supervision the work of inspecting immigrants became more uniform and thorough. Suitable buildings had to be erected, and other expenses necessary to the rigid enforcement of the law were incurred. It became evident that the head tax of fifty cents was inadequate for defraying the expenses incident to immigration. By a provision in the sundry civil bill, approved August 18, 1894, the head tax was increased to one dollar.

In June, 1900, congress enacted that the commissioner general of immigration should have charge of the administration of the Chinese Exclusion Law.

After ten years of trial, the law of 1893 was found inadequate in some particulars, and a great popular demand for further restriction was manifested. As a result of this popular demand the law of 1903 was enacted. By the provisions of this act previous legislation was amplified, and further necessary restriction placed on undesirable classes of immigrants. The head tax was increased to two dollars. The authority to deport aliens landed in violation of law, was extended to a period of three years from the landing of such alien. In addition to

the undesirable classes excluded under previous laws, we find in this act that epileptics, and 'anarchists or persons who believe in or advocate the overthrow, by force or violence, of the Government of the United States, or of all Government, or of all forms of law, or the assassination of public officials' are excluded.

The utter disregard shown by the steamship companies for United States laws in permitting diseased persons to take passage for America, when their diseased condition must have been apparent, was responsible for the imposition of a penalty of one hundred dollars for bringing to our ports any alien suffering from a loathsome or dangerous contagious disease, which might have been detected by means of a competent medical examination, at the time of embarkation.

It will be noted from the foregoing summary of immigration legislation that nearly all the laws have been passed since 1880. It is a significant fact that previous to that time immigration came chiefly from Great Britain and Ireland, Germany and the Scandinavian countries. With the rapid and progressive increase of immigration from Russia, Austria-Hungary, Italy, and other countries of southern and eastern Europe, deterioration in the quality of immigration was sufficiently marked to indicate the necessity for more thorough regulation and restriction. The favorite method of evasion of our immigration laws was to send the questionable immigrant by way of Canada. By the courtesy of the Canadian government and by virtue of an agreement with the transportation companies our officers are permitted to examine, at Canadian ports, immigrants destined to the United States through Canada, but defective immigrants evaded this inspection by being manifested as destined to Canada. The Canadian law was formerly much less exacting than our own, and these people after landing and remaining in Canada a short time, could slip over the border without inspection. An effective system of border inspection was instituted by the United States immigration authorities, to prevent the smuggling of these immigrants across the Canadian border. The difficulty of guarding over three thousand miles of frontier can be appreciated, however, and the passage of a Canadian law (1902), at least approaching our own standard, has been welcomed as an addition to our defenses.

The provision made for excluding anarchists and persons of like tendencies has already been applied to some of these disturbers, and promises to be very effective in this direction.

Our contract labor laws have been materially strengthened by the act of 1903. There is no longer ground for misapprehension as to whether the laws were to apply to unskilled labor alone—or to both skilled and unskilled.

THE ROYAL PRUSSIAN ACADEMY OF SCIENCE AND THE FINE ARTS. BERLIN.

By EDWARD F. WILLIAMS,

CHICAGO, ILL.

IV. From the Reorganization in 1812 through the Reign of Frederick William III., to 1840.

THIS period was a period of great men in almost every branch of learning, especially in science, of great statesmen and historians, of great warriors and rulers. It was a period in which the intellectual life of Germany developed rapidly, in which the gymnasia were much improved, in which the new science of teaching was created, in which the universities, more especially those of Prussia, stimulated by the standards set up at Berlin, became worthy of a kingdom and the patronage the world has given them.

During the reign of Frederick William III., or from 1812 to 1840, the character of the academy changed very little. Its statutes were modified only when absolutely necessary, although under the influence of the Humboldts and their sympathizers it became, what it was organized to be, an institution for research, and through its publications, for the diffusion of knowledge. In the early decades of the nineteenth century Germany began to take her true place as a leader in scientific, historical and philosophical studies. She sought to make her own what Cousin, the French philosopher, describes as 'the true, the beautiful and the good.' The unity of all branches of learning became apparent. It was in this new era of intellectual life that some of the great undertakings for which the academy has acquired fame were planned and set on foot. Men like Niebuhr, Schleiermacher, Savigny and Boeckh felt the need of an institution which would consider and execute enterprises for the diffusion of knowledge which were far beyond the resources of private individuals. One of these enterprises, and one in which Boeckh was deeply interested, was the gathering, arranging and publication of Greek and Latin inscriptions. Out of the discussions in which Boeckh and many others engaged have come the volumes of Latin inscriptions to which Mommsen gave so many years of his life and which with their vast amount of information will ever remain a monument to his industry, scholarship and rare skill as an editor. The volumes of Greek inscriptions are of scarcely less value than those of the Latin. Another result of the departure from traditional methods has been the edition of the works of Aristotle,

including comments on his writings and such annotations by present-day scholars as have seemed necessary. It was through Wolff, one of the members of the academy, who died in 1824, that German scholars were made acquainted with the treasures of Grecian archeology. In the second decade of the century, great as was the ambition of many of its leaders, the academy was by no means what it now is. At its regular sessions rarely more than one half its members were present. Only 8 out of 29 or 30 who might have had the privilege heard Schleiermacher's remarkable essay on 'Various Methods of Translation.' The philosophical class, of which Schleiermacher was the head, contained only two members in addition to himself, Savigny and the younger Ancillon. It was the historical class which led the academy. To it belonged William von Humboldt, Ideler, Niebuhr, Buttmann, Boeckh and Bekker. In the decade following the fall of Napoleon the works of Savigny, the Grimm brothers, Lachmann, Bopp, Diez, Carl Ritter, Niebuhr, the Humboldts, Eichorn, Creutzer, Gottfried and Hermann appeared. Many of them were epoch-making. Schleiermacher represented philosophy, philology and theology, as well as ethics, in his writings and in his instructions as a professor in the university. Boeckh represented philology, history and economics, while Niebuhr made it plain in his Roman History how history should be studied and written. Savigny indicated in his writings on law how closely united it is with history and philosophy.

It was in 1815 that Boeckh proposed and secured the adoption of a plan for the publication of all accessible Greek and Latin inscriptions. He thought the work might occupy four years and cost about $450. It is not yet entirely complete and has cost more than $45,000. Boeckh gave his personal attention to Grecian antiquities and with the aid of a commission appointed by the academy, by correspondence with societies in Corfu, Thessaly and Athens, and by searching the libraries of Europe, gathered material for a work which he soon discovered would be far more extensive, valuable and costly than he had originally anticipated. Bekker came to his aid and was made his permanent assistant in 1817. He had spent the years 1810–12 in Paris, copying manuscripts, and in 1815–16 had been employed with Professor Goeschen in Verona in copying the 'Gaius,' discovered by Niebuhr while serving as ambassador in Rome, a work which has proved to be of importance for the science of law. In 1817 Bekker was entrusted with the preparation of the writings of Aristotle, which was subsequently made to include the comments and everything else which could throw light upon their meaning or their importance. Professor Brandis was chosen as his assistant. This edition, now under the care of Professor Diels, is approaching completion and is of inestimable value to all who prize learning and painstaking accuracy. Mr. Diels entered the academy in 1882 and is still one of its most important members. Bekker devoted

the years 1817–20 to careful study of the material in the libraries of Italy, Holland, Belgium and France as a preparation for his editorial work, which began in April, 1821. Although it was decided as early as 1817 that an edition of Grecian inscriptions should be published, nothing was actually done to bring this about till 1826. Prior to this last date it had become evident that it would not be enough to publish inscriptions which had already appeared, as Zumpt proposed, or were in the libraries, but that all of them must be copied anew from the ruins and monuments on which they were found and then patiently studied and criticized by the best scholars of the day. For defraying the cost of this undertaking, a grant from the government was sought and obtained. A third work of very great importance interested the academy and received a good deal of assistance from it, the Monumenta Germaniæ. So important was this work that the Society for the Study of Old German History was organized to care for it, a society in which all German-speaking countries have shown an interest. A long step forward was taken by the academy in 1821, when it secured a printing-press of its own, with fonts of type in Arabic and Sanscrit as well as in Greek, Latin and German. Of course, there were troubles with the printer, but it was now possible for the academy to watch closely its own work and to send it out into the world in such shape as it desired. Henceforth the 'Transactions' or 'Proceedings' appeared in a greatly improved form.

There were many serious discussions among the members of the academy as to the wisdom of retaining four distinct classes, each with its own special secretary or director. Some like Schleiermacher wished the number reduced. He did not care to have the philosophical class continued. He and its members preferred to be in the historical class. Others thought science had been neglected, although as many men prominent in its various branches as could be persuaded to come to Berlin had been invited thither as members of the academy or as professors in the university. Minister Altenstein in 1820 sent an order to the academy to put a statement of the changes it desired into writing, but with the understanding that the philosophical class would be retained, and the historical class, if possible, be made more efficient. That meant that the four classes would be continued substantially as they were.

Meanwhile the government had grown suspicious of Schleiermacher and Savigny. They were looked upon as 'demagogues and spies.' The police were ordered to listen to Scheiermacher's sermons. William von Humboldt was dismissed from the cabinet as Cultus minister because of the liberality of his views, and the academy was rebuked for publishing such papers as those of Niebuhr. A decree was issued on October 19, 1819, by order of the king, which forbade any member of the academy to publish anything, whether literary or scientific, without

the approval of the government censor. Thus the right of free publication, which the academy and its members had long enjoyed, was invaded, and in spite of protestations, freedom of publication was suspended for five years, and was not formally removed till July, 1843. But a petition for freedom on the part of the academy to issue its official papers without submitting them to censorship was favorably received by the king, although that privilege was denied to its members as individuals.

The physical class of the academy, stimulated by what the historical class had accomplished, set itself about great enterprises. In 1820 it sent Ehrenberg, who had already won fame as a microscopist, to Egypt. He and Hanpricht, his associate, explored the Libyan desert, Lower Egypt, Upper Egypt as far as Nubia, the coast of the Red Sea and passed through Arabia, Petrea and Syria. To the funds required in 1823 the king made generous gifts from his private resources. The year 1825 was given to travel and study in Abyssinia. In the 85 boxes sent to Berlin at different times there were geological specimens of great variety, many fossils, a large selection of dried plants, as well as of woods, fruits, seeds, weapons and instruments in use in northern Africa. Of animals there were above 4,000 different specimens in ten times that number of individual examples, and 2,900 specimens of plants. This journey and its outcome were significant for both the academy and the progress of science.

The scientific section of the academy put forth a special effort in 1825 to strengthen its influence by securing men of the first rank for its various departments. As the astronomer had failed to keep abreast of the times, Oltmans and Encke were brought into the academy. Encke served it forty years, and till 1863 was secretary of the mathematical class. It was through his influence and discoveries that the academy gave such an impulse to astronomical studies. The new building for astronomical uses, begun in 1832, was completed in 1835, and $375 a year for six years was set aside by the government for its support. A map of the heavens was planned, on which the position of all fixed stars above the ninth and tenth magnitudes was to be shown. The heavens were divided into 24 sections and assigned to as many observers. It was supposed that the map, which was a pioneer of its kind, would be completed in four years. In fact, it was only partially completed in 1859, but it prepared the way for the more accurate and extensive work of later days. Not a little was done by the historical class in archeology, and the need of special funds and accurately trained laborers in this field was seen to be so pressing that in 1829 the Archeological Society of Berlin was formed. Aid was given Graff for a German dictionary and to Bopp for an edition of the Indian poem, 'Mahabharata.'

Hegel's philosophy with its theories of panlogism and its doctrine

of the absolute, was not favorable to science. Yet it enjoyed the confidence of the government and in many circles was accepted as true. But to Schleiermacher and not a few others its theories seemed fanciful and uncertain. Perhaps it was on account of their unwillingness to receive him into the academy that in 1826 he and a few others founded a society for scientific criticism with the three departments of philology, philosophy and history. This society, to which some distinguished men attached themselves who might otherwise have been in the academy, till some time after the death of Hegel was influential in Berlin. Regular sessions were held, and year books, two volumes each year, from 1827 to 1840, were published.

It was in this last year that the philosophical class, now reduced to two members, was given up, and its work transferred to the historical class, of which, since Buttmann had become too old to discharge its duties, Schleiermacher became secretary. During the first third of the century the philosophy of the absolute had the field. It was in the second third of the century that natural history and religion entered the lists against it and won the victory. And yet the reign of science in Berlin began with the return to that city in 1827 of Alexander von Humboldt, who had lived twenty years in Paris in close association with Liebig, Arago, Gay Lussac, Bonpland and Valenciennes, to all of whom he was warmly attached. At that time the academies of Paris were at the height of their fame, as eminent in their different fields as the university of Paris had been in the middle ages among the other universities of Europe. Humboldt had rare skill in gathering and grouping facts, and the publication of his 'Cosmos' was a great event in the scientific world. Yet its leaves were hardly dry from the press before its conclusions were outgrown. But the spirit and method of the book, writers like Harnack say, will survive.

The winter of Humboldt's return was full of excitement for learned circles in Berlin. In the university he lectured on the 'Cosmos,' and sixteen times he spoke on the physics of the world to an audience which filled the Singakademie and represented every class of society from the king to a stone mason.

Between 1830 and 1840 many of the more prominent and useful members of the academy passed away—Niebuhr, Seebeck, Rudolph, Schleiermacher, William von Humboldt,—and new men were added—Dirrichlet, Ranke the historian, Eichorn the critic, Hoffman the statesman, Graff, Stein, Johannes Müller, G. Rose, Gerhard, Dove the meteorologist, Poggendorf, Neander the church historian, and Magnus—every one of whom contributed not a little to the increase of knowledge and to the fame of the academy.

For some reason the physical class was now growing more rapidly than the historical class, for there had in reality ceased to be more than these two classes, and efforts were made in the early thirties to

render them more nearly equal. But the objection to Hegel on the part of many, and the admiration felt for him on the part of others, made it well-nigh impossible to elect any one to the historical class. This abnormal condition of things was brought to an end by the sudden death of Hegel on November 14, 1831. A commission was appointed to see if some means could not be devised for reducing the four so-called classes of the academy to two, a mathematical-physical class and a historical-philosophical class, the arrangement which now exists, but which was not brought about till 1838, although the difficulties between the classes had long before passed away. By special decree on March 31, 1838, many desirable changes were favored and made legal by the king. In 1837 it had been definitely decided that the academy should stand for research, chiefly in science and literature, that the number of members should not exceed fifty, equally divided between the classes, and that each class should nominate only one hundred corresponding members. The mathematical-physical class voted to have two members each for chemistry, physics, botany, zoology and anatomy, and six for the mathematical sciences. In May, 1839, the historical class proposed three members for the study of philosophy and its history, three for the study of general history, two each for archeology, mythology and oriental literature, four for the old classical literature, one member for the study of German philology, and one for the study of politics.

With this arrangement of its forces the academy could now be defined as 'a society of learned men organized to advance and spread general knowledge apart from the function of teaching.' It was agreed that each class should determine and direct its own work, that special meetings for each class should be held once a month, general meetings each week, that no person should belong to two classes at the same time, that each class should propose its own members, though they must be elected by the vote of both classes of the academy and that vote confirmed by the king. The right to lecture in any Prussian university was made one of the perquisites of members of the academy. Ordinary members were paid $50 a year, the botanist, the chemist, the astronomer, two philologists and two historians, more than twice as much. The four secretaries while managing their special sections were to preside in turn at general meetings four months each.

Three public meetings were appointed for each year, Frederick's Day in January, Leibniz Day in July and the king's birthday. For January the program was to be a general history of the year; for July, an account of the special work done. Persons not belonging to the academy could be employed for special service, but only two men at a time for each class, and not more than $300 a year could be paid out for this kind of work. With slight modifications these arrangements and regulations are still in force, although the members are paid $225 (900 Marks) each a year, and divisions into sections in the

academy made for convenience and efficiency are all now embraced in the two classes already named. The king died in 1840. At that time the income of the academy from all sources was a little more than $15,000. It had not increased materially since 1809, and yet out of this small income some money had been saved and invested as capital. The king had preserved the independence of its members save in regard to the censorship exercised over their private writings, and had entrusted its care to wise advisers. During this reign, advance in knowledge, especially in scientific directions, had been very great. The academy had done some excellent work in all the departments of knowledge which it represented. In mathematics, worthy of mention are Dirrichlet, Steiner, Weierstrass, Jacobi and Kummer. When only twelve years, Dirrichlet spent his money for books on mathematics. From the Cologne gymnasium he went to Paris to hear La Place, Legendre, Forier and Poisson. He not only could understand Gauss's 'arithmetical disquisitions,' but he could make their meaning clear to others. He married Rebecca Mendelssohn Bartholdy in 1832, and after that time till his death his house was an intellectual and social center in Berlin. In the estimation of those who know it best his work was as important as that of Descartes in the use of analysis in geometry. Astronomy made good progress under Encke. His study of the occultation of Venus in 1796 enabled him to determine more accurately than had ever been done the parallax of the sun. In physics many names have become famous. Paul Ermann and Seebeck were in the academy before Frederick William III. occupied the throne; Dove, who laid the foundation of the science of modern physics; Poggendorf and Magnus came in prior to 1840. Ermann was in the academy from 1806 to 1851, was one of its secretaries from 1810 to 1841 and did as much as any one to help forward its development. DuBois Reymond was accustomed to speak of him as one of the best physicists of his era and as preparing the way for physicists like Magnus, and physiologists like Johannes Müller. Magnus was trained in chemistry by Berzelius and Gay Lussac, and in his turn trained many of the best modern chemists of Germany. Seebeck, after laboring thirteen years in the academy, withdrew to Jena, living upon his private means and devoting himself wholly to scientific studies. Mitscherlich, the discoverer of isomorphism, and Heinrich Rose, the discoverer of niobium, were trained by Berzelius and as analytical chemists have been ranked with their teacher. J. B. Karster, Weiss and G. Rose were eminent as mineralogists, and Leopold von Buch is credited with having laid the foundation for the study of geology and paleontology in Germany. His geological map in twenty-five leaves, published in 1821, had in 1843 run through five editions. For many years Link was the keeper of the botanic garden in Berlin, and with his own money founded its present magnificent herbarium. Harkell and Kunth were associated

with him in his work. The latter spent sixteen years in Paris on a collection of plants carried thither by Alexander von Humboldt, and at his death left a herbarium containing 55,000 specimens, which the government was wise enough to purchase. Zoology and anatomy were represented in the academy by Rudolphi, Lichtenstein, Ehrenberg, Klug and Johannes Müller. The first named was director of the zoological museum, which he made the finest in Europe. He was author of 'Journeys in South Africa.' Klug worked in entomology for more than half a century, and at his death left the museum more than 80,000 species of insects in more than 260,000 specimens. He gave no little attention to the study of spiders and shells. Ehrenberg is famous throughout the world as a microscopist. The titles to his papers, his reports to the academy and his works fill twenty-five pages in the quarto catalogue of the academy. In anatomy and physiology the studies of Müller, who was twenty-five years in the academy, were epoch-making for the science of biology. It is admitted that he made physiology a science. Alexander von Humboldt was recognized as the most distinguished man of science of his generation. Devoting himself to no single department of science, he became eminent as a man of almost universal knowledge. At his death the king consented that his friends should establish a fund in his memory, the income of which is available under the direction of the academy for journeys in various parts of the world in the interest of such studies as Humboldt himself had most eagerly pursued. Carl Ritter was the founder of the scientific study of geography. Ideler combined the study of modern languages, in which he was an adept, with the study of mathematics and astronomy. F. A. Wolff gave himself to philology, a science which he did a great deal to form and develop. Niebuhr, Buttmann, Boeckh, Bekker, Suesmilch were ornaments to the academy. The last named was followed by Lachmann and Meineke, and these in turn by Hirst and Uhden, who began the study of archeology, which E. Gerhard did so much to push forward into the prominence it deserves. In Rome Niebuhr gathered many manuscripts, which were of use in the preparation of the Latin inscriptions. Though a librarian, Buttmann gave himself to lexicography and grammar. While England and America are deeply indebted to him for his 'Grammar of the Greek Language,' which first appeared in 1820, it is not too much to say that he made the study of that language popular and scientific for his native land. Lachmann, who lived from 1793 to 1851, was a born critic. He was a student of old dialects of modern languages, as well as of the classics and of the text of the New Testament. Zumpt was distinguished as a Latinist and for his grammar of that language. E. Gerhard was famous as an archeologist, but was most useful in carrying through Mommsen's plan for gathering, collecting, arranging and publishing the Latin inscriptions. Francis Bopp came to Berlin at the suggestion

of Humboldt and was made professor of oriental languages in the university. He devoted himself mainly to Sanscrit, and published his dictionary of that language in 1827. The first part of his 'Comparative Grammar,' by which his fame was gained, appeared in 1852. Other editions appeared at different times from 1856 to 1862, and the last edition shortly after his death in 1868. To him all orientalists owe a debt of gratitude. Jacob Grimm gave himself to the study of the German language and William von Humboldt to the study of the philosophy of language, in which his writings are as important for the science of law as those of Linnæus for the science of botany. Every one knows what Niebuhr did for history, which he studied in the belief that knowledge of it is of value for the present day. Boeckh found his chief interest for the time in which he lived, in the study of life and government among the ancient Greeks. Bekker was famous for his studies of Homer, his editions of Provencial works, his studies in old French and Italian and in modern Greek. From him Lachmann learned the true method of criticism. Wilker and Friederich von Raumer were students of universal history, the latter being known for his 'History of the Crusades.' Savigny and Eichorn were historians of law, as Niebuhr was of Rome and Neander of the church. Savigny is the founder of the historical school of jurisprudence, and immortalized himself in a six-volume history of 'Roman Law in the Middle Ages.' K. E. Eichorn is the father of the history of German law. Von Ranke, who died in 1886, stands at the head of modern historians. As he went to the original sources for what he wrote, his books will not soon lose their value. Hoffmann, the statesman, became famous as a statistician and a political economist. It is said of him, as of no one else in his time, that he knew how to arrange statistics scientifically and to deduce ethical lessons from them. He was director of the Prussian bureau of statistics and made it one of the most valuable in Europe. These are some of the men who were in the academy during the period under treatment and whose names are sufficient to furnish reasons for the fame it attained and for the share it had in contributing to the knowledge of the world. Indeed it has been proudly said that no volume of the 'Proceedings' during this period is without some treatise which either founds a discipline or lifts an older one to a higher grade.

V. *The Academy under Frederick William IV., 1840 to 1859.*

Not since the days of Frederick the Great had there been so warm a friend of the academy on the throne as the new king. He was willing to identify himself with the academy by attending its public meetings as Frederick had not been. Save in the realm of politics and theology he granted it full liberty of discussion and publication. He was very friendly with Alexander von Humboldt, whom he had as a

constant guest at his table, through whom he kept himself informed as to the progress of science in Europe and the special needs of the academy. He favored the new learning and the new methods of study, but he did not favor radical measures in politics nor changes in the creeds or in the methods of governing the church. Yet he brought the Grimms, Haupt and Mommsen to Berlin, radical as he knew them to be in their political opinions, and secured their election to the academy. From him came the money for the publication of the Latin inscriptions and for the beautiful and complete edition in thirty volumes of the works of Frederick the Great, Vol. I. appearing in 1846 and Vol. XXX. in 1856. He interested German scholars in Egyptian research and made it possible, by private gifts, for Lepsius to spend the years from 1842 to 1845 in the study of its monuments and its curious learning. He helped Agassiz to come to America, Rosen to go to the Caucasus, Petermann to Syria, Palestine and Arabia Petrea, and Peters to South Africa. He aided Graff on his Old High Dutch collection and Schwartze in his Coptic studies. He provided means with which Dove pursued his meteorological researches and for the establishment of institutes in connection with the universities for the training of teachers. In 1842 he founded the order *pour le mérite* and the Verdun prize to be given once in five years for the best German book issued during that period. It is interesting for Americans to know that this prize was awarded to the late Professor von Holst for his 'Constitutional History of the United States.' And yet the relation of the academy to the government was not quite so pleasant as it had been during the ministry of Altenstein. The new ministers were not all so profoundly convinced of the usefulness of the academy as was the king, but they did not fail to aid it or cease to advise the king to sustain it. At his death the great work on German inscriptions, to which he had given much thought, was approaching completion.

In passing, it may be observed that the first written word ever sent the academy by Mommsen was in a letter of thanks, dated April 2, 1843, for a grant of a little less than $120 for aid in his studies of Latin inscriptions in and about Naples. One of his last reports was read in the academy in 1903. Not only was the academy with great difficulty persuaded to undertake the publication of the Latin inscriptions, it was with still greater reluctance that it entrusted the gathering and arranging of them to so young a man as Mommsen. He was backed by men like Savigny and Lachmann, and the first installment of his work proved even to those who had doubted it his fitness for the undertaking. Yet it was not till seven years had passed, called by Gerhard his 'seven years' war,' that Mommsen was finally given entire control of the work, with power to choose his own assistants and proceed in his own way. Meanwhile he had sent the academy 450 inscriptions, most of them copied with his own hand, 100 of which

could not be found in the libraries of Europe and 150 of which had never been published. During the discussions concerning himself and his relation to the inscriptions he retired to Leipzig as a professor and thence to Zürich, where he began his 'History of Rome.' In his new work in the 'Inscriptions' Italian scholars freely offered their assistance, some of them without asking for pay, so that when the king pledged $2,000 a year for six years there was no reason for hesitating to send the young scholar back to Italy. In 1857 he was transferred from Breslau, where he had been made a professor, to Berlin, given a chair in the university and elected to active membership in the academy. He became one of its most useful and prominent members, and at his death in 1903 was one of its most famous. Vol. IX. of the Latin inscriptions was published in 1862, and in the same year the 'Monumenta Priscæ Latinitatis.' Each year of this reign from $1,500 to $1,750 was expended, apart from special grants, for purely scientific purposes. Yet, in spite of its limited means, never exceeding $15,000 annually, the savings of the academy in 1857 had reached the sum of $25,000.

The death or withdrawal of many of the older members of the academy and the introduction of new members, many of them young men, brought a great change into its spirit and methods. The Grimm brothers were in the academy thirty years and did very much to increase its usefulness and its reputation. The second edition of Jacob Grimm's 'German Grammar,' the first edition appearing in 1822, contains his law of sound and gives its author a place by the side of William von Humboldt and Francis Bopp as one of the founders of the modern science of language. After the death of Stein, G. H. Pertz was entrusted by the Society for Old German History with the editorship of the 'Monumenta Germaniæ,' a work which but for his diligence and his skill might never have been finished. It was through his advice and persistency that the academy was induced to publish the 'Annals of Leibniz.' In 1844 Jacobi, second only to Gauss as a mathematician, was brought from Königsberg to Berlin and the academy. He devoted himself to the study of the functions of the ellipse. His writings for six years fill two of the quarto volumes of the academy. Trendelenberg, whose strength as a philosopher lay in his skill as a critic, and in his knowledge of all previous thought, was instrumental in inducing the academy to undertake the publication of the works of Aristotle. Peterman was famous for his acquaintance with the Armenian, Semitic and Coptic languages, and Homeyer for his studies in the middle ages and for his ability to trace in a scientific manner the history of law during that era, and to give his contemporaries a correct understanding of the history and development of German law. Of what Lepsius did for the science of Egyptology few are unaware. During the fifties the zoologist Peters; the physiologist DuBois Rey-

mond; Kosch and Baum, the botanists; Buschmann, the linguist; Pinder, the numismatist; Riedel, the historian; Curtius, linguist as well as historian; Kiepert, the geographer; Haupt, the philologist; Beyrich, the geologist; and Ewald, the paleontologist,—entered the academy and by the investigations in their special departments of study and their publications did their full share in increasing its fame throughout the world. When DuBois Reymond was a candidate for the academy, Alexander von Humboldt and Johannes Müller, his backers, described him as 'a fine experimenter in physics, physiology and chemistry' and added that 'he had been carefully trained in mathematics and the classics.' Reymond became one of the best known members of the academy, was in it forty-five years and lived for it as no one had done since the days of Merian. In 1850–51, Barthomess of Frankfurt, an honorary member of the academy, published what Harnack describes as a philosophical history of the academy. It covers the period from Leibniz to Schelling, and within its limits, Trendelenberg says it is unsurpassed. Notwithstanding the excitements in Berlin, as well as elsewhere on the continent of Europe, of the year 1848, and the anxiety caused by the failing health and the mental weakness of the king nearly a decade later, the members of the academy quietly performed their tasks and through its publications added something every year to the aggregate of human knowledge. Not a few of its members were recognized throughout the world as leaders in the departments of study to which they had devoted their energies. Alexander von Humboldt, who died in 1859, having been connected with the academy, either as honorary or as active member, since the beginning of the century, was present at one of its regular sessions in March as eager for knowledge as in his youthful days. With his death and that of Carl Ritter and William Grimm a great era in the history of the academy closed. But before entering upon that chapter of its history which unites it with the present, we may call attention to the fact that in 1845 Prescott, Sparks and Bancroft, American historians, were made corresponding members, that in 1852 Dr. Edward Robinson, the distinguished biblical scholar, was added to the list, and that in 1855 the same honor was accorded to Professor James D. Dana, the geologist, and Professor Asa Gray, the botanist.

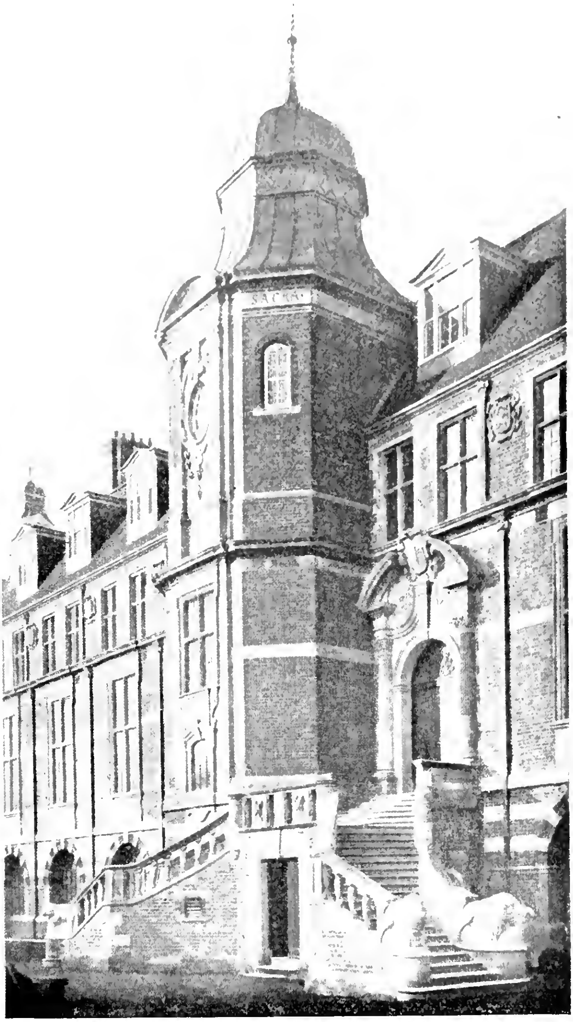
THE PROGRESS OF SCIENCE.

THE NEW BUILDINGS OF CAMBRIDGE UNIVERSITY.

On the first of March four new buildings were opened at Cambridge by King Edward. One of these is a law school; the others are for the natural sciences—a medical school, a botanical laboratory and a geological museum. The great English universities have found difficulties in meeting the requirements of modern science. The colleges were richly endowed, though unequally; and they have suffered in recent years from the depreciation in the rents of agricultural lands. The lecturers and coaches of the colleges could give the instruction needed in the languages and in mathematics, and to a certain extent in other subjects such as the political and mental sciences, but they could not provide laboratories for the natural sciences. The universities were almost without endowments, and they have been very slow in coming either from the state or from private gifts. In 1882 a commission required the colleges to contribute toward the support of the university. In 1897 special efforts were made at Cambridge to secure an endowment fund, which resulted in gifts amounting to about $350,000, rather a modest sum, according to American ideas, but sufficient with the other resources at hand to warrant the erection of four new buildings.

Geology at Cambridge had its beginnings in the bequest of Dr. John Woodward, who in 1727 drew up a will leaving to the university his cabinet of fossils and an income of £150, from which a lecturer was to be paid to read at least four lectures every year in defense of the doctrines of the founder. It appears that lecturers were duly appointed who did not lecture, until in 1818 the office was assigned to Adam Sedgwick. In the following fifty-five years, Sedgwick made Cambridge a great geological center. After his death in 1873, a committee collected a fund ultimately amounting to about $125,000, to which the university added about $100,000, and the Sedgwick Memorial Museum has been built from designs by Mr. T. G. Jackson. Professor Hughes, Sedgwick's successor in the Woodwardian chair, says of the building: "Skilfully designed, and carefully executed, it will enable us to display the finest educational collection in the world. This was what Woodward aimed at in his day of small beginnings, and what Sedgwick worked for during his whole academic career. The great museum occupies the first floor of both wings, and amid the long series of specimens which scientific geology has revealed to us, Woodward's ancient cabinets are piously preserved in a small enclosure special to themselves. On the ground-floor are the products of the earth's crust which are of economic value, with a large lecture-room. On the second floor are class-rooms, and private-rooms for the different teachers, with the noble library, the fittings for which were provided by the liberality of the late master of Trinity Hall. In the attics are more rooms for research, and large store-rooms where specimens can be unpacked, sorted, and determined before they are placed in the museum."

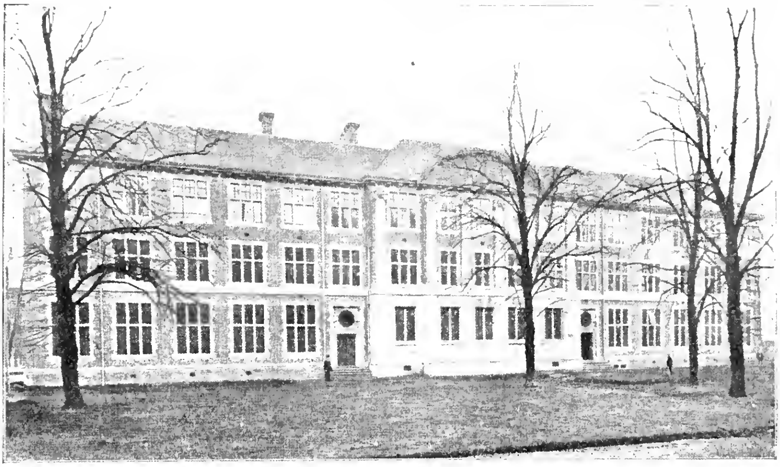
The building for the botanical school is less imposing than the Sedgwick Museum, but appears to secure good effects by its proportions. So far as can be judged by the illustrations and ground plans, it presents a good type of laboratory building, with ample light and convenient arrangements. The build-



THE SEDGWICK GEOLOGICAL MUSEUM.

ing has doubtless been made for the laboratories and lecture rooms, not as sometimes happens in university architecture, imitated from some model built at a time when there were no laboratories. A hundred years hence such buildings will probably appear in better taste and more truly beautiful than our gothic and classic imitations, built without reference to their uses. The cost of the botanical building paid from the endowment or benefactors fund mentioned above is about $130,000. It contains in addition to the herbarium and museum and a large elementary laboratory, laboratories for physiology, morphology and chemistry, and some ten private and research rooms. The engineering department has taken over the room formerly used for botany.

The Medical School Building with



The Botanical Laboratory.

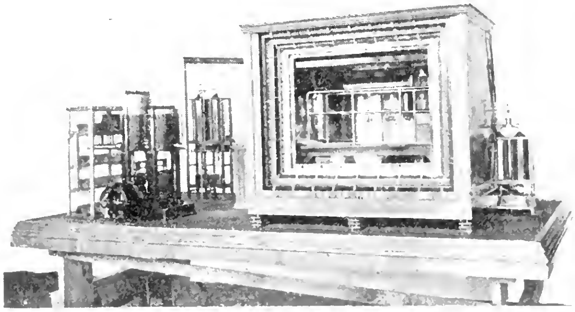
The Humphry Museum and The Medical School.

the Humphry Museum has been erected at a cost of about $170,000, mostly supplied by the benefactors fund, and a further wing for pathology and physiological chemistry is planned at a cost of about $65,000. The Humphry Museum is treated ornamentally, both inside and out. The fact that the main lecture-room is lighted entirely by artificial light, might lead us to suppose that utility had been sacrificed to architecture, but it is said that the building is well adapted to the uses of the medical school. The library is planned on a new principle, the stacks being blocked solidly on the sides, each case being movable and pulled out when wanted. This scheme seems to be ingenious; the space is nearly trebled and books are kept free from dust. It is doubtless a disadvantage to shut the books from view, but when the case is pulled out the books are more accessible than in ordinary stacks.

The buildings here mentioned are erected on land acquired by the university from Downing College, and three of them form part of an irregular quadrangle. It is hoped that a school of agriculture and an archeological museum will be added to the group within a reasonable period.

DEVELOPMENTS IN THE RESPIRATION CALORIMETER.

Two important developments have lately been made in this apparatus, which render it a more efficient means of determining the use which is made of food nutrients in the body, and extend its use to experiments with large animals. As is well known, the apparatus as developed by Atwater and Rosa enabled the accurate determination of the carbon, nitrogen and water excreted by the subject within the respiration chamber, and the heat given off by him under different conditions of food and exercise. During the past year an alteration has been made in the apparatus by which the oxygen consumption is also determined, giving increased accuracy and furnishing data for estimating the gain or loss in protein and fat, as well as a new method of estimating the respiratory quotient. The arrangement for determining the oxygen is new and very ingenious. In adapting the apparatus to it, it has been changed from what is known as an 'open-circuit' to a 'closed-circuit' apparatus, *i. e.*, the same air is used over and over again, the products of combustion in the body of the subject (carbon dioxide and water) being constantly removed by passing the air current through sulphuric acid and soda lime, and fresh oxygen supplied to take the place of that consumed in the respiration. The oxygen content of the air current is kept practically constant and normal. The accuracy of the modified calorimeter for measuring heat has been tested by a number of electrical check

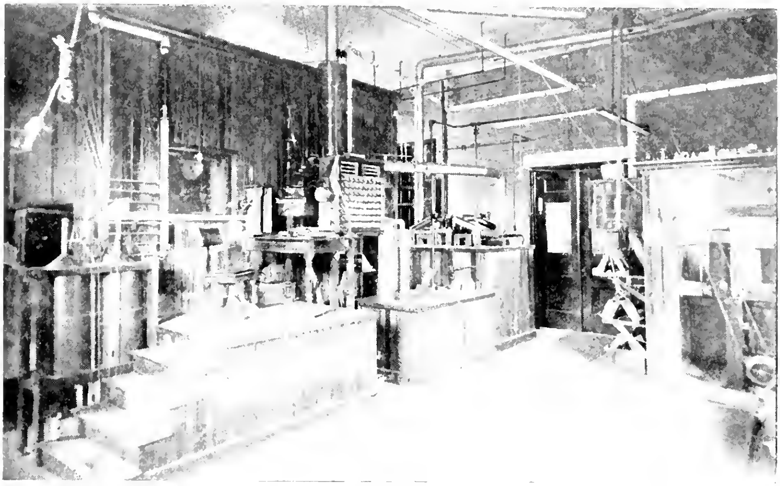


MODEL OF THE ARMSBY-FRIES RESPIRATION CALORIMETER.

experiments, and by the combustion of alcohol in a specially devised lamp.

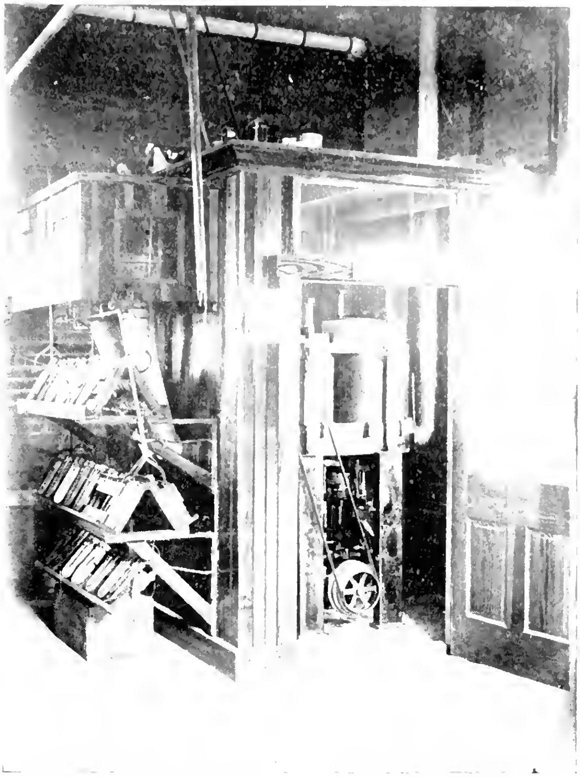
As indicating the character of the work carried on by Professor Atwater with this apparatus, a recent experiment may be cited. In this the subject remained in the respiration chamber for thirteen consecutive days, making the experiment the longest one on record and in many respects the most complete. There were three days of work on a so-called sugar diet, three days on a fat diet, one day of hard work on a fat diet, two days of fasting, and four days on a light and very simple diet, the subject sleeping or lying down during one day, sitting up one day, and two days doing light work on a bicycle provided with an ergometer for measuring the work. The observations were unusually complete, including in addition to the carbon, hydrogen and heat, the oxygen and the income and outgo of sulphur and phosphorus. A record of the body weight was also made by a new method in which the subject was weighed from the outside.

The adaptation of the respiration calorimeter to use with farm animals marks a decided advancement in the method and facilities for studying the fundamental principles of animal nutrition. This has been accomplished by Dr. H. P. Armsby and J. A. Fries, who, working in cooperation with the Bureau of Animal Industry of the Department of Agriculture, have constructed an apparatus of this type at the Pennsylvania Experiment Station. In adapting the apparatus to experiments with large animals, it was necessary not only to increase the size of the respiration chamber, but to introduce a considerable number of special features so that the operations of feeding, weighing, collecting the excreta, etc., could be performed entirely from without. Among the most interesting of these are the devices for weighing the heat absorbers from the outside, the air lock for introducing feed and water without allowing the escape of air from the respiration chamber, and similar devices for the collection of the liquid and solid excretory products.



Armsby-Fries Respiration Calorimeter.

By check experiments the apparatus has been found to be very accurate, the measured heat being practically identical with the theoretical amount produced by burning alcohol in the respiration chamber. In ordinary



METER PUMP AND ABSORPTION TUBES (ARMSBY-FRIES APPARATUS).

metabolism experiments with animals the amounts and composition of the food and of the urine and feces are the factors considered. Using this apparatus it is possible to determine the total income and outgo of both matter and energy. The apparatus affords opportunity for investigation in a great variety of important lines, and for checking the results secured by the more practical feeding experiments. It is especially adapted to studies of such questions, for example, as the energy required to digest and assimilate different classes of feeding stuffs, the food requirements of animals under different conditions, and the replacing value of nutrients.

An experiment recently reported with the apparatus, the first one to be published, was on the available energy of timothy hay. In this a large steer was used, and there were four periods, each covering two days in the respiration chamber. This first experiment gave results of much interest from both a scientific and a practical standpoint, and clearly demonstrates that for studies on the nutrition of animals, as well as of man, the possible lines of investigation with the respiration calorimeter range from the most practical to the most technical subjects.

It is worthy of mention that the Armsby-Fries apparatus is a distinctly American product, and is the only one of its kind in operation in the world. A similar apparatus, modeled after it, is being constructed at the agricultural academy in Bonn, Germany, but is not yet in operation.

THORIUM, CAROLINIUM AND BERZELIUM.

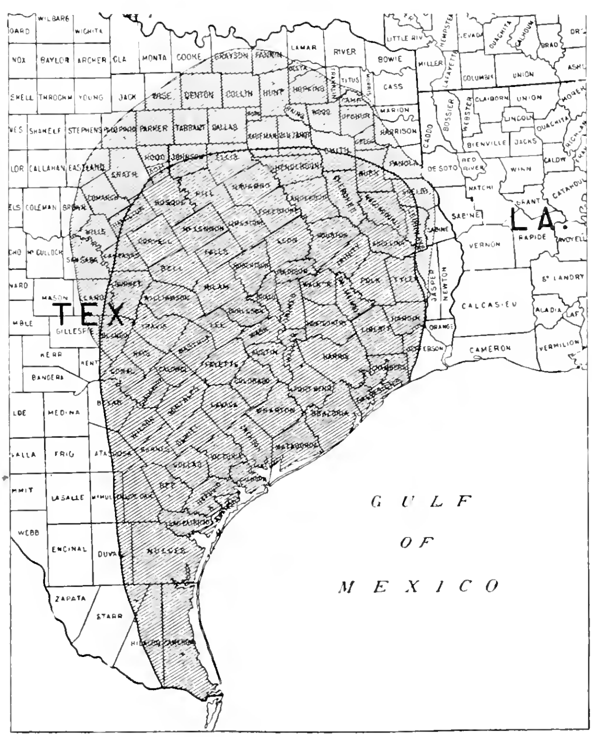
In a paper entitled 'Thorium, Carolinium, Berzelium,' presented at the Chemists' Club, New York, the evening of April 8, by Dr. Charles Baskerville, professor of chemistry at the University of North Carolina, the following interesting and important facts were brought out. As the result of a number of years' study of the element thorium, Dr. Baskerville has succeeded in extracting from it two novel chemical elements. The work indicated an agreement with the conclusions of Hofmann and Zerban in opposition to those of Schmidt, Curie and Rutherford, namely, that thorium is a primary radio-active body. Although no thorium preparations had yet been prepared absolutely free from any activity, numerous reasons were given which pointed toward the correctness of the conclusion that thorium is not a primary radio-active element. An extremely interesting observation touching this may be noted, namely, a preparation was obtained from a large amount of the wash waters used in the manufacture of the Welsbach mantles which was very much more radio-active than the original thorium and yet showed no thorium by chemical methods, and the merest trace was found in the spectrum made with a large Rowland grating. Whether it be primarily radio-active or not, the speaker maintained would not interfere with the other conclusions obtained from the investigations of himself and a number of his students.

Pure thorium was fractioned by phenyl hydrazine and the fractions obtained varied in their atomic weights from 214 to 252, the original thorium showing 232.6. That method was abandoned as time-robbing, and an effort was made to separate the constituents by fractional distillation of the chlorides as they were made by passing chlorine over a mixture of pure carbon and thorium dioxide. Very elaborate apparatus was devised for this purpose, the mixture being placed within a carbon boat and the distillation carried out within quartz tubes. A white vapor was given off at a comparatively low temperature which condensed in the cooler portion of the tube and was readily collected by solution in alcohol. The thorium was distilled away from the boat and collected as fern-like crystals of the tetrachloride within the quartz tube. A residue remained in the boat. These three materials were more or less purified and atomic weight determinations made of them. That which remained in the boat after different methods of purification showed an atomic weight of 255.6. Its oxide gave a specific gravity of 11.26, the original thorium having an atomic weight of 232.6 and specific gravity of 10.5. The original thorium oxide was pure white, whereas this residue possessed a pinkish tinge. This is the carolinium of the new element reported by Dr. Baskerville in 1900. The volatile body gave an atomic weight of 213, assuming its quadrivalence. The oxide gave a specific gravity of 8.44. It possesses a slight green color. As Berzelius first noted this 'Meisserdampf,' stating that it was not thorium, the author named the element berzelium after the famous Swedish chemist who discovered thorium. The new thorium gives a white oxide and shows an atomic weight of 220. The specific gravity of this oxide is 9.2. Carolinium oxide is soluble in hydrochloric acid. Neither of the other oxides, nor the original thorium oxide, is soluble in this acid. All the oxides show radioactivity. Several chemical differences were also noted. The speaker carefully stated that the materials were not yet in the state of purity that was desired. He stated that none of these substances gave absorption spectra. Some slight differences had been noted in the arc spectra, but no definite conclusions could be drawn. Samples of the materials had been sent to Sir William Crookes, by request, who is

at present engaged in mapping the spectra in the ultra-violet region. Chemists have agreed to accept an element only when a definite atomic weight and characteristic spark spectrum are had. To be sure such important observations require verification in the hands of others as well.

THE INSECT ENEMIES OF COTTON.

That the high price of cotton is partly due to the abundance of certain insect pests in the south is strikingly shown by the two maps, which we reproduce, showing the distribution in Texas of two of the more important insect enemies of cotton. The boll-worm has long been known as injurious to cotton, corn and other crops, in foreign countries as well as in the United States. The Mexican cotton boll weevil, at present the most serious menace to cotton culture, has spread northward from Mexico during the past ten years, until now it occupies the greater part of the Texan cotton belt, and has entered Louisiana. Both of these insects live within the boll or carpel of the cotton plant; and at present there is no way of combating them save by cultural methods. The government has appropriated a considerable sum of money for an investigation of these insects, and a number of scientists, under the Department of Agriculture, are now at work in Texas and Louisiana. The present status of



Map showing distribution of cotton boll weevil in the United States in 1903. The heavy line indicates the limit of the region in which the weevils have multiplied to such an extent as to be found in all cotton fields; the remainder of the shaded portion indicates the region in which colonies are known to exist.

MAP OF TEXAS SHOWING REGIONS RAVAGED BY THIS BOLLWORM IN 1903.

this investigation and the means of control which the work of the department has shown to be most feasible are detailed in Farmers' Bulletin No. 189 relating to the cotton boll weevil, and in Farmers' Bulletin No. 191 relating to the cotton bollworm, from which publications the two maps presented herewith are taken.

SCIENTIFIC EDUCATION IN SCHOOLS.

THE council of the Royal Society has adopted and submitted to the universities of the United Kingdom the following resolution:

"That the universities be respectfully urged to consider the desirability of taking such steps in respect of their regulations as will, so far as possible, ensure that a knowledge of science is recognized in schools and elsewhere as an essential part of general education."

The council has also appointed a committee, which has drawn up a statement in regard to the teaching of science in schools, which reads as follows:

"Notwithstanding efforts extending over more than half a century, it still remains substantially true that the public schools have devised for themselves no adequate way of assimilating into their system of education the principles and methods of science. The experience of 'modern sides' and other arrangements shows that it can hardly be expected that, without external stimulus and assistance, a type of public school education can be evolved which, whilst retaining literary culture, will at the same time broaden it by scientific interests. On the other hand, it is admitted that many stu-

dents trained in the recent foundations for technical scientific instruction have remained ignorant of essential subjects of general education.

"The bodies which can do most to promote and encourage improvement in these matters are the universities, through the influence which they are in a position to exert on secondary education. This improvement will not, however, be brought about by making the avenues to degrees in scientific or other subjects easier than at present. Rather, the test of preliminary general education is too slight already, with the result that a wide gap is often established between scientific students careless of literary form and other students, ignorant of scientific method.

"It may be suggested that the universities might expand and improve their general tests, so as to make them correspond with the education, both literary and scientific, which a student, matriculating at the age of 19 years, should be expected to have acquired; and that they should themselves make provision, in cases where this test is not satisfied, for ensuring the completion of the general preliminary education of their students, before close specialization is allowed.

"In particular, it appears desirable that some means should be found for giving a wider range of attainment to students preparing for the profession of teaching. The result of the existing system is usually to place the supreme control of a public school in the hands of a headmaster who has little knowledge of the scientific side of education; while the instructors in many colleges have to deal with students who have had no training in the exact and orderly expression of their ideas.

"Our main intention is not, however, to offer detailed suggestions, but to express our belief that this question of the adaptation of secondary education to modern conditions involves problems that should not be left to individual effort, or even to public legislative control; that it is rather a subject in which the universities of the United Kingdom might be expected to lead the way and exert their powerful influence for the benefit of the nation."

SCIENTIFIC ITEMS.

We regret to record the deaths of M. Emile Duclaux, director of the Pasteur Institute; of Sir Clement Neve Foster, professor of mining in the Royal College of Mining, London; of Professor A. W. Williamson, the eminent British chemist; of Sir Henry Thompson, the distinguished surgeon; and of Sir Henry M. Stanley, the African explorer.

At the recent meeting of the National Academy of Sciences members were elected as follows: Professor William Morris Davis, Harvard University Professor William Fogg Osgood, Harvard University; Professor William T. Councilman, Harvard Medical School; Professor John U. Nef, University of Chicago. The foreign associates elected were: Professor Paul Ehrlich, Frankfurt; Professor H. Rosenbusch, Heidelberg; Professor Emil Fischer, Berlin; Sir William Ramsay, London; Sir William Huggins, London; Professor George H. Darwin, Cambridge; Professor Hugo de Vries, Amsterdam; and Professor Ludwig Boltzmann, Vienna. The Draper gold medal was presented to Professor George E. Hale, of the Yerkes Observatory, Wisconsin, for his researches in astrophysics.

The trustees of the British National Portrait Gallery have received by bequest from the late Mr. Herbert Spencer a portrait of himself, painted by J. B. Burgess, R.A., and a marble bust of himself by Sir J. E. Boehm.—The certificate of incorporation has been filed of the Walter Reed Memorial Association for the purpose of securing funds to erect a monument in Washington City to the memory of the late Walter Reed, major and surgeon U. S. Army. Dr. Daniel C. Gilman is presi-

dent, and General George M. Sternberg, vice-president of the association.

Lord Kelvin has been unanimously elected chancellor of the University of Glasgow in the room of the late Lord Stair.—Professor W. Ostwald gave the Faraday lecture of the Chemical Society at the Royal Institution, London, on April 19. At the close of the lecture he was presented with a medal bearing the image of Faraday, which had been specially struck for the occasion. Cambridge University subsequently conferred on him the degree of doctor of science.—The Bruce Gold Medal of the Astronomical Society of the Pacific has been awarded to Sir William Huggins for distinguished services to astronomy.

Dr. John M. Clarke, paleontologist of the state of New York, has been appointed geologist and director of the State Museum.—Dr. F. S. Earle, assistant curator of the New York Botanical Garden, has resigned to accept the office of director of the new agricultural station in Cuba. The station will occupy a farm and buildings at Santiago de la Vegas, about twelve miles from Havana. The sum of $75,000 has been appropriated for the establishment and maintenance of the station for the first year.—Among the distinguished lecturers at the summer session of the University of California, which begins on June 27, are Professor Svante A. Arrhenius, of the University of Stockholm; Professor Hugo De Vries, of the University of Amsterdam; Sir William Ramsay, of University College, London, and Professor James Ward, of the University of Cambridge.

The corporation of the Massachusetts Institute of Technology has instructed its executive committee to confer with the Harvard University authorities on the subject of closer relations between the two institutions.—A Massachusetts Zoological Society has been incorporated with a view to establishing a Zoological Park in Boston.

K. Mitsukuri Boston, 1898

THE
POPULAR SCIENCE
MONTHLY.

JULY, 1904.

A VISIT TO THE JAPANESE ZOOLOGICAL STATION AT MISAKI.

BY PROFESSOR BASHFORD DEAN,
COLUMBIA UNIVERSITY.

JAPAN is not at its best in the rainy season. For the rain comes down in floods. And my first impression was that Misaki was a larger aquarium than even a zealous naturalist needed. We had left Tokyo at six—I was about to say, early one morning, but I recall that six is not early in Japan—on a small bay steamer which plies daily to Misaki. And a few hours later we had about reached a climax in our rolling, when, turning suddenly, we ran under the lee of an island and came to anchor. I confess that I was not cheered by the glimpse of Misaki: the town was a flat, sodden mass of thatched houses, its background an abrupt knoll, with a ragged skyline of dripping and irregular pines, and the drooping eaves of a temple. And to add to the dismalness of the picture, even the sampan men appeared tearful as they shedded streams of rain from the points of their porcupine-like coats. Our fellow passengers, on the other hand, showed not a symptom of discomfort, and they clambered smilingly into the sampans, standing or crouching under a mass of oil-paper umbrellas, men often tucking up their kimonos and standing bare-legged like storm-bound birds—their wide wooden clogs giving them the appropriate webbed feet. Ashore was waiting for us an assistant of the station, Mr. Tsuchida, and together we waded through the narrow and fishy streets of the town (which I found, to my surprise, had a population of five thousand, and was of no little commercial importance in furnishing fish for the Tokyo market) to the Inn Kinokuniya. This inn I recall vividly, for its host, in spite of the drenching rain, thought it necessary to hunt the town for a knife and fork for the foreigner, and while

about it borrowed a chair and table, probably from the station house and its solitary policeman, and provided 'beefu teki' and 'pan' (bread), in order to make things homelike, as he said. And while he busied us with these incidentals, he engaged a sampan to carry us to the station. I might mention that in *real* Japan the traveler can, or should, do little without the aid of his innkeeper—if one wishes to go to the railroad, a theater, a shop, or to hire a boat, a coolie, a jinrick-

The Misaki Zoological Station.

shaw—it is *de rigeur* to go first to the ever-present inn. I soon discovered that our host was on excellent terms with the zoological people, for the station had formerly been located near by in the town. But the town was found to be not the best of locations; there was too much noise, and—fish market, for example—so the building was moved bodily around the point to a small rugged peninsula which forms the harbor of Aburatsubo, about a mile away. Presently our host shelled us in rain coats and deposited us in our sampan, and our ferryman, sculling with a heavy balanced oar, shot us beyond the island, whose lighthouse guides the steamers into the mouth of the bay of Tokyo, and then, turning sharply, he skirted the coast, around the edge of the sea of

Sagami. At this point of the trip I recall that some confusion was created, as we rounded a swell-swept rock, by our sailor falling overboard, his oar becoming suddenly unshipped, an incident remembered mainly on account of the poor fellow's embarrassment. We pulled him into the boat and reinstated him; and he shook off his dripping kimono and stood naked in the drenching rain; bronze body, white loin cloth, white band knotted around his forehead, pressing down a fringe of bristling black hair, his muscles showing splendidly as he swayed at his oar, hissing viciously as he pushed and pulled. In a few minutes more we rounded a little pine-covered point, and the two white buildings of the laboratory came into view.

BEACH OF THE CASTLE OF ARAI, SEEN FROM THE STATION.

The taller of these, two-storied, is the one which was removed from the town of Misaki in 1897, the other was built a couple of years later. Together they stand close to the water, but are sheltered from typhoons by an abrupt hill which forms the end of the point. The surroundings are beautiful. A number of inlets cut deeply and irregularly into pine-covered hills, and in nearly every direction one obtains vistas of

bluffs, pines and rocks very much as at famous Matsushima. Altogether I believe that the student here enjoys more picturesque natural surroundings than at any other laboratory in the world. And we may add to this the unzoological item that the headland has a romantic background. For here was the castle of Arai, famed in Japanese history as having withstood for several years the siege of the Hojo regents during the fourteenth century: and on every hand are memories of its past glory.

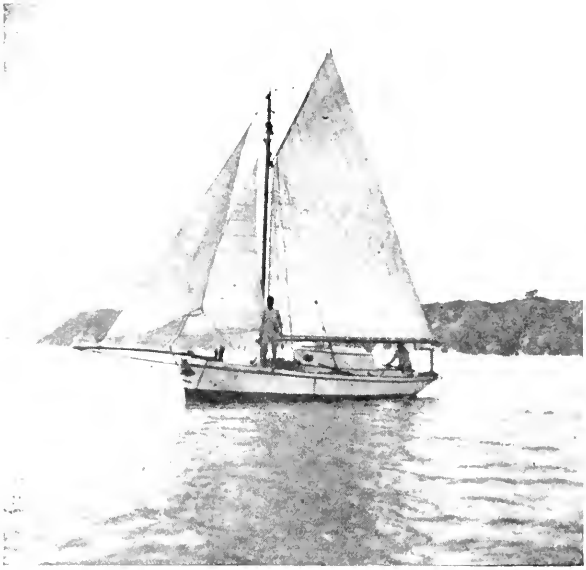
THE MARINE STATION AT MISAKI.

If I digress a bit, I might point out that the student dormitory, amid the old pines on the hilltop above the laboratory, and next to Professor Mitsukuri's villa, is built on the exact site of the ancient castle, and here interesting relics have been found; such, for example, was a fragment of a splendid gold-crested helmet dug up during my stay. Near by are traces of fortifications, and a store-room excavated in the rocky bluff during the ancient days of the castle. The bay, at the side of the laboratory, is still called the 'Red Harbor,' because at

its very edge the defenders were beheaded after the sack of the castle. And just opposite is the 'Buried Treasure-Beach,' where the most valuable plunder of the castle is supposed to have been stored. And more interesting still are the monuments marking the spots where died by hara-kiri the lord of the castle, Dōsun Miura, and his son, after word had been brought them that all hope was lost. The local story is that Dōsun Miura retired to this point after witnessing the death of his son, and fearful lest his own head should be carried across the bay to Odawara by the conquerors, he would trust no one to act as his second in the death ceremony. Seizing his short cue with one hand, *he is said to have cut off his own head with the other, and to have thrown it far out in the deep water before his body fell*, a physiological possibility, by the way, which students of the laboratory do not question—in the presence of townspeople. So the greatness of the Miura is unimpaired, and every year memorial services are celebrated on the laboratory grounds. At this time portrait-images of Dōsun and his son are brought from a neighboring temple and placed on the altar in a prayer-tent near the beach, and wrestling bouts commemorate the siege and the fall of the castle. Perhaps I might end my digression with the note that the present property came into the hands of the imperial family and has remained unoccupied since the fifteenth century. The major reason for this is said to have been that the point was haunted and many curious stories are told of the reappearance of Dōsun Miura and his men on the hilltops among the ancient pines. One recognizes them readily, since, like all Japanese specters, *they have no feet*. Indeed, I learned through Mr. Alan Owston, of Yokohama, that even a few years ago, when his yacht anchored overnight at Aburatsubo, the point was still so ghost-ridden that the sailors were unwilling to go ashore!

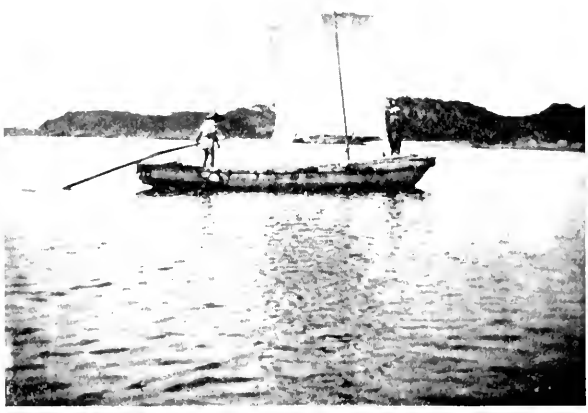
As for the zoological station itself: The one-story building is used by the graduate students, and is divided off in alcoves in the usual way. Work places for eight investigators are provided on the north side of the main room. On the south side of the building is the office of the director, and forming the fourth corner of the building is a concreted room containing aquaria and giving ample space for the preparation of larger material. By a covered way one passes from the door of the advanced laboratory into the two-story building, the ground floor of which is used at the present time for general class work. The upper story contains two living rooms fitted in European style, which were generously placed at the writer's disposal by the authorities of the Zoological Institute.

The general class work consists of a summer course of about six weeks' duration, which gives its members an opportunity of becoming familiar with the structure of the prominent animal types. The stu-



'Arai,' the Collecting Boat of the Station.

dents, about thirty in number, are usually teachers of zoology in various high schools throughout Japan. Some of them live in the dormitory on the hilltop, others find lodgings at the neighboring fishing village of Aburatsubo, often hiring quarters in the little temple on the top of



A Fishing Boat.

the hill. The investigators include Professor Mitsukuri, one of the founders of the station and its director, and usually the greater number of the staff of the zoological department of the Science College. Professor Ijima frequently comes down to visit his reefs of glassy sponges, Professor Watasé, Professor Goto, Dr. Izuka, Dr. Miyajima, Mr. Namiyé, some of the younger assistants, and three or four of the graduate students of the institute at Tokyo make up the remaining corps of investigators. During the writer's visit, a Russian ichthyolo-

A Crew of Fishermen.

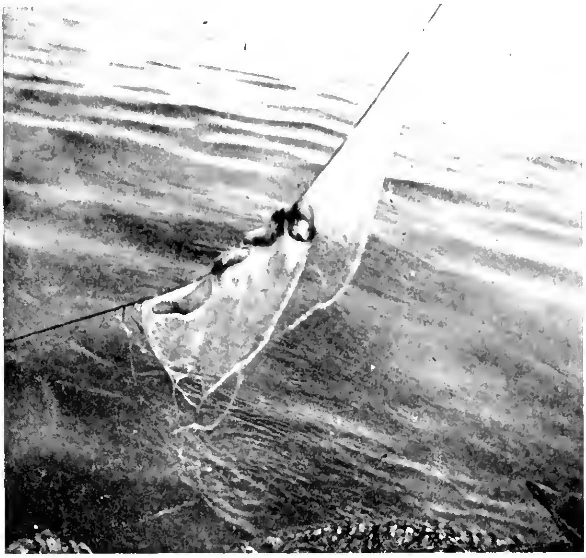
gist, Professor P. Schmidt, became a guest of the station, and an American zoologist, Mr. J. F. Abbott.

The work-quarters, it may be mentioned, are simple, but all necessary appliances and books are promptly forwarded from the institute at Tokyo. It is the collecting facilities which the visitor does not forget, for not only is the locality a rich one, but the ways and means are at hand to secure material even from great depths. And in this lies the value of neighboring Misaki, for during many months of the year the fisher people set out at sunrise in their large boats, proceed

off shore to well-known fishing reefs, which, by the way, are often in very deep water, and return during the afternoon with a varied haul. If successful, their home-coming is spectacular—they chant in chorus and push their heavy boat through the water, sometimes skulled by as many as a dozen oars, at the rate of a young steam launch, the boat garnished at the prow, and the crew wearing fillets and loin cloths of scarlet. It happens, fortunately, that the fishery is carried on principally by hand trawls, for it is clear that when such a line, which is sometimes a mile in length and with thousands of dependent hooks, is pulled up again, even if fish are not taken, there will surely be entangled a varied collection of objects—sponges, echinoderms and rock fragments, the last often richly stocked with brachiopods, worm tubes, corals, bryozoa. Happily, too, the collector of the station, Kuma Aoki, is an ex-fisherman, for, knowing the townspeople, he serves as a diplomat, suggesting regions which should be fished, and often accompanying the expeditions. To be mentioned in this connection is the skill with which the fisher people are able to locate accurately fishing grounds. By the use of a system of cross ranges, a master of the craft like Kuma can return to a spot where he has lost a valuable fishing line, and can secure it on a following day—a result which seems the more remarkable to the novice when he reflects that the line may have been lost in 400 fathoms of water.

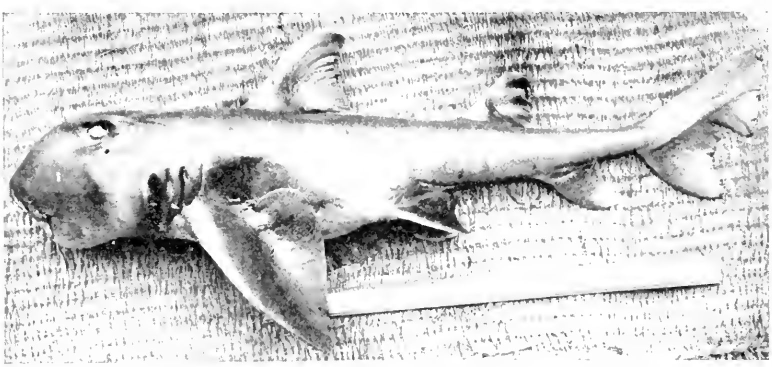
While the trawl line is the customary apparatus of the fishermen, numerous devices are also employed in special fisheries, an account of which has been given recently by a Russian ichthyologist (cf. Dr. P. Schmidt, *MT. d. Deutschen Seefischerei-Vereins*, No. 2, p. 31, 1903). I might mention particularly the use of earthenware urns which are fastened together by straw rope, and sunken in the coves in the neighborhood of the station. These are constantly used by octopus as places of retreat during bright daylight, and to secure them the urns have merely to be overhauled from time to time. Shell fish are often taken in the usual eastern way by the use of a water glass and a dart-pointed bamboo pole, or, without a water glass, the fisherman may simply thrust his head below the surface of the water. Especially useful to the collector are the numerous divers of Misaki, who are, I may add, so skilful that they use no apparatus, not even weights for rapid descent, but will swim down duck fashion, to a depth of twenty or thirty feet. They hunt especially *Haliotis*, examining the rocks deliberately, and often remaining below several minutes. I may mention that one of the familiar sounds which one hears when rowing in the neighborhood of the station is the diver's peculiar whistle, by which he expands his lungs before descending.

One need hardly review the fauna in the region of Misaki. It is enough, perhaps, to say that here focus many favorable conditions for



A Living Hag-fish, Showing a Mass of Freshly Secreted Slime.

marine collecting. There is a rich shallow water fauna which yields, among other delectable things, *Amphioxus*, sea-pens, a giant *Balanoglossus*, *Onchidium* and a *Phoronis* four inches in length. In the immediate neighborhood of the station can be obtained at low tide *Antedon*, very abundant, *Lingula*, the spawning of which Mr. Yatsu has observed in the laboratory, and *Cœloplana*, the latter discovered by Mr. Abbott. Pelagic forms can also be collected favorably. *Pyrosoma*, *Appendicularia* and *Salpa* are abundant. Various ctenophores, including *Cestus*, are not uncommon, and near the station, sometimes sweeping close to the shore, is the Black Current, bringing many southern forms. I may mention that the dead shells of *Nautilus* have been



A Freshly Caught Port Jackson Shark.

picked up near the station. The richness of the neighborhood in deep-water forms has been well known since the studies of the *Challenger*. Glass sponges of many species are frequent prizes of the fishermen. And stalked crinoids (*Metacrinus rotundus*) are often taken off the reef Okinosé. Among the fishes *Bathythrissa,* a primitive deep-water teleost, of which the *Challenger* was able to obtain but few examples, is now taken off Misaki so abundantly that it is regularly shipped to the fish-market in Tokyo. Hag-fishes are common, even more than common, and there have been collected within a relatively small area three genera and four species. Among the sharks *Heptanchus* is common; *Mitsukurina,* which is perhaps the Cretaceous broad-nosed *Scaphanorhynchus,* is taken occasionally. A Port Jackson shark is abundant, and in the course of a year the neighborhood yields about a dozen specimens of the frilled shark, *Chlamydoselachus.* Of chimæroids, *Chimæra phantasma* is common, and *C. mitsukurii* and *C. purpurescens* also occur; rare, however, is the long-nosed chimæra, *Rhinochimæra pacifica.*

One need hardly remark that the possibilities of Misaki are not exhausted in producing new and extraordinary forms. To cite merely an instance of this, during the writer's visit two hag-fishes were obtained, one of which, *Paramyxine atami,* was transitional between Myxine and Bdellostoma—its outer gill openings being drawn together within the length of about a centimeter; another (*B. okinoseana*) was transitional between the hag-fishes of many and of few gills, a large form with eight gill-openings on either side. In fact, it is coming to be expected that each year is to bring to the Zoological Institute at Tokyo prizes from Misaki—one year new forms of sponges; another, a gigantic tubularian hydroid, *Branchiocerianthus,* as a 'gift from the sea goddess Otohimé'; and another, specimens of umbrella-shaped octopods, *Amphitretus.* Under such circumstances it is not unnatural that the visitor should bring away from Misaki a stronger impression of his individual work in collecting—and this implies a clearer picture of the local fauna—than from many an older and better known zoological station. And he might justly add that the friendship of his colleagues of Japan is not the least enduring memory of his stay.

HUGO DE VRIES'S THEORY OF MUTATIONS.*

BY PROFESSOR A. A. W. HUBRECHT,
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THE theory of evolution has influenced human thought in the most various ways during the past half century. In the sphere of biological science, where Darwin sowed the seeds which have grown up with such unexpected luxuriance, there has been a continuous process of fermentation which shows no signs of subsiding.

Still it has often seemed as if the immense mass of facts, which Darwin collected and arranged with so much care and skill, were provisionally looked upon as sufficient, and as if actual experiment were no longer a primary necessity. Whenever a new observation happened to be made, it was in danger of being drowned in pailfuls of theoretical considerations. Genealogical trees were planted, grafted, transplanted and finally often committed to the flames. Statistics were brought together to demonstrate the importance of natural selection, not only in the struggle between individual organisms, but also within the organism between the elements of which it was composed. Thus Roux wrote in 1881 his 'Kampf der Theile im Organismus,' Weismann only a few years ago (1896) his 'Germinal Selection.' In a series of very remarkable publications the Freiburg professor of zoology has thrown light on a series of difficult problems and has shown himself to be not only a faithful pupil of Darwin, but one who on several occasions has been more ultra-Darwinian than perhaps Darwin himself would have been.

Those who consult the very voluminous literature of the subject will soon be convinced that the number of biologists who have preferred patient experimentation to theoretical speculation is very limited indeed. Experimentation on this subject demands a great deal of time, of patience, of devotion, and is liable to meet with many pitfalls. Yet for those who came after Darwin this should have been the task that lay closest to their heart: to test the two great groups of facts on which descent and selection are founded, by means of new and more detailed experiments.

These two groups of facts are the phenomena of heredity and of

* This article was written in English by Professor Hubrecht, the eminent Dutch zoologist, who has an equal command of the French and German languages. Professor de Vries is at present in the United States in order to lecture at the University of California and other institutions.—EDITOR.

variability. Heredity, the conservative factor, by which what was once acquired is multiplied and rendered stable; variability, by which there appear side by side with those forms that are hereditarily constant, others which, being perhaps in yet closer harmony with the environment and with the prevailing conditions of life, may thus obtain a chance to defeat the first and to supplant them, with the prospect, however, of being in turn ousted by yet more closely adapted new forms, more exactly fitted to the surroundings. The mutual interaction of these two factors, heredity and variability, shows that a continual tendency in organic nature prevails, by which life proceeds from the simple to the more complicated, from the more primitive to the more perfect. And the archives in stone that have been opened to us by the geologists contain ample proofs to convince us that during the succession of thousands and thousands of centuries, plant life and animal life all over the world have passed through a similar process of development.

When Darwin was writing his 'Origin of Species' the chapter on 'Heredity' in physiology was yet a book sealed with seven seals. During the last forty years, especially during the latter twenty, several most important pages of that book have been closely studied and partly deciphered. The conviction has begun to dawn upon us that the phenomena of heredity, assimilation and growth do not belong to different categories, and that, furthermore, this so mysterious heredity can be traced to the minute material particles with which it is bound up, and which through the whole range of plants and animals show an unexpected uniformity.

The labors of such men as Hertwig, Boveri, van Beneden, Strasburger, Guignard and many others, who have made a study of heredity, are especially important, because they have succeeded in analyzing the phenomena into their component elements, thanks to careful observation and experimental testing. They have shown us how very much we may yet expect from experimental work. In the next few years we may, no doubt, look forward to a rich harvest in this extensive field of investigation.

Variability is the name of the second group of facts, on which the slow development of higher, better and more complicated types of living beings rests. Here, too, we must call for the facts and ask for the credentials of the theories we meet. There is ample proof that in the domain of variability we encounter many delusive traps and a host of difficulties. Even Darwin has not spun out to the end the thread of comparative experimentation. It has been reserved to Hugo de Vries to point this out in a very remarkable book ('Die Mutationstheorie,' Leipzig, 1901–1903) that has just been completed.

For nearly twenty years Professor de Vries has been busy making

experiments on a large scale on variability in plants, and the results of those experiments have enabled him to formulate gradually his own thoughts and to compare them with the teachings of Darwin, Wallace and others. Those who are acquainted with the patient experiments of the Amsterdam professor and have assimilated his results, will agree that, by the publication of this book, a new leaf has been turned in the history of evolution. A set of new facts has been gathered with which all those who of late years have theorized about Darwinism must reckon, and which will undoubtedly prove to be the starting-point for further experiments in the direction they so clearly indicate.

I shall now try to point out: (1) in what respects de Vries's work is such a very decided step in advance; (2) in how far it might be supposed that there is any conflict between Darwin's opinions and those of de Vries; and (3) to what extent a teleological interpretation of nature might draw upon the results of de Vries's investigations.

Supposing there existed no variability in nature, life would lose a good many of its attractions. Fancy men and women resembling each other like so many drops of water, both physically and morally! Fancy all dogs constructed according to one pattern, all flowers, all trees of one species being absolutely identical as to their branches, number and shape of leaves, etc.! Fortunately, from our very childhood we have learnt to see nature in a different light, and we have all contracted the habit of giving our preference to the finest and best horses, flowers and playfellows; permanent selection is thus being exercised by us, which can add much to our happiness in life. In effecting it, we make use of what variability offers, and, consciously or unconsciously, we always tend to favor the better and to decline the worse.

Yet more intensely than in the way just sketched, the variability of living organisms is utilized by those who make their livelihood by the rigorous application of selective principles to plants and animals. Dealers in seeds of improved plants, nursery gardeners who cultivate rare varieties of flowers, breeders of birds and domestic animals, all these have a direct interest in every change for the better or for the worse, and are very keen at increasing the former and eliminating the latter. Any one who sells corn or maize, which, when sown under the same conditions, produces ears doubly full or yielding flour of a better quality, may be certain of a substantial gain. One who cultivates beet-roots containing a greater amount of sugar gains equally. Again, a man who lays out a considerable amount of money in purchasing mares and stallions beautifully fit for racing purposes, and who breeds from these with care, will not only be paid back the money he spent, but find means of quickly doubling his capital.

The improvement of our domestic animals, the development of our wheat, the diversity in color and in shape of our decorative plants,

have long been objects of constant effort. Whole classes are constantly occupied in making the most of the phenomena of variability, as much for their own advantage as for the benefit of the community. If we consider the results thus obtained we can not fail to notice that the plants and animals in question have grown to differ so much from the original stock that, should we meet with them in nature, we should undoubtedly call them new species, perhaps even new genera. It follows that if man can in this way direct the phenomena of variability to his own use, the origin of species of plants and animals in nature may depend on a similar series of phenomena.

In nature, however, the selecting breeder is replaced by an automatic process—the survival of the fittest in the struggle for life. That struggle occurs in the first place between members of the same species; it is a struggle for food, light and air, for fecundation and thus for reproduction.

But such a struggle for existence, by which the fittest remain alive and gradually supplant the less fit, does not take place only between individuals of the same species; it is also waged—and perhaps more effectually—between closely allied species.

In this conception the final decision will be reached by the cooperation of very numerous circumstances. It finally leads to a sifting process, to the disappearance of many and to the selection of a few. Selection is a self-regulating phenomenon; it is nature that chooses, and the name of 'natural selection' is thus amply justified. According to Darwin and Wallace, who simultaneously formulated the principle, the origin of species is brought about by 'natural selection.' It is the counterpart of the voluntary or 'artificial selection,' to which man owes the improvement of various cultivated plants and domestic animals. The material out of which in both cases new races and new species are being created, is that which variability offers: the struggle for existence in nature, the breeder in his hothouses or in his kennels, shapes the material into new races, varieties and species.

We thus find ourselves compelled, whenever we wish to penetrate more deeply into nature's laboratories where new species are being fabricated, to sift most carefully the whole and complicated set of phenomena which we call variability. Only in this way may we hope to approach by means of our imagination the coming and going of different forms of organized life that have succeeded one another since the cooling of our planet, and of which only a small portion have been preserved as fossils since the Silurian epoch.

Darwin inaugurated the sifting process with wonderful sagacity. Wallace has continued the work, but has wandered away from reality (as de Vries will teach us) to a considerable extent. Darwin was well acquainted with the fact that two kinds of variability should be dis-

tinguished: one, which is called fluctuating variability, oscillates round a mean value; we shall consider it a little more closely. Whichever characteristic of a species we happen to choose, we shall always find, in considering a number of specimens, that individual differences, individual variations, can be noticed which, when tabulated according to size or to number, do not exceed two opposite extremes. Half-way between these extremes we find the 'norm' for that particular characteristic. The fluctuation may be represented by a curve, the culminating point of which corresponds to the norms just mentioned, whereas to the right and to the left of it the curve gradually approaches the horizontal line and has a symmetrical shape. Quételet and Galton have insisted on the great significance of the fact, that fluctuating variation remains enclosed within the limits of such a curve of regular shape; the curve itself is, therefore, often called Galton's curve.

Not only for plants, but also for animals and especially for man, the existence of such Galton curves, expressing the amount of variability, has been definitely established by different observers in very numerous instances. Thus, for example, Ammon has obtained his material from South German recruits. We need not insist on the fact that the greater the number of cases, the more reliable the curve.

The different degrees of fluctuating variability can undoubtedly be seized upon by any one who wishes to make them the starting-point for the breeding of certain distinct variations. Thus, for instance, by constantly selecting for the reproductive process those plants in which a given deviation is strongly marked, after a certain time and after a series of generations, a plant can be obtained for which the Galton curve would indicate a displacement of its culminating point in the direction of the selected variation. In this way an increase in the yield of sugar obtained from the beet roots has been arrived at from about 7 per cent. to 13 or 14 per cent. Thus also ears of maize have been produced that bore 20 rows of grain, whereas the kind from which the experiment had started always bore 12 to 14 rows.

As soon, however, as such conscious and voluntary selection ceases, the next generations successively return to the original curve. In order to prevent this retrograde process, without a constant and repeated application of the artificial selective process, we are obliged to prevent the appearance of new generations, by forcing the plant to reproduce itself not by seed, but asexually by means of buds. It is well known that definite kinds of delicate fruit are reproduced in this fashion, because if multiplied by seed, they would always tend to fall back into their former state of less value. Transposing the culmination of the curve of variability artificially, as explained, or breeding variations to the right or to the left of the norm, can never exceed certain limits. Agencies are at work there which prevent the fluc-

tuating variability from going any further. The existence of such limits compels us to acknowledge that there is no possibility that species might arise in nature according to the same plan by which certain breeds originate under artificial selection.

On this point de Vries and Wallace differ essentially. The latter is convinced that the fluctuating variability is the only source from which new species have gradually originated; de Vries, however, is quite justified in claiming that the examples of the increase and the accumulation of certain variable characters do not prove that a new species or subspecies has ever arisen in that way in its natural environment.

But in addition to the fluctuating variability we have now to consider another variability, regarding which both Darwin and Wallace have collected numerous data, the so-called 'single variations,' which do not follow the Galton curve. They are not connected with their starting-point by very gradual transformations, but are separated from it by a measurable distance which they have overcome, not by degrees, but by starts. They have, therefore, been named 'sports' or 'saults,' the leap being in different cases larger or smaller.

We have seen that fluctuating variability leads to slow changes and furnishes farmers with the material to improve the races of animals and plants. The 'chance variations' in their turn are valued quite especially by horticulturists and nursery-gardeners.

The English name 'single variations' expresses very well, indeed, the difference between the two kinds of variability. Fluctuating variability shows us simultaneously all the different degrees between extremes, as represented by the descendants of a single parental pair. The single variations, on the contrary, stand isolated; they are discontinuous; between them and the original parent form we do not observe any gradation. This difference has long been noticed, and on several occasions the difference between these 'single variations' and fluctuating' or 'oscillating variations' has been insisted upon.

De Vries has accepted the name 'mutation' and has submitted the phenomenon to a severe experimental test. The chief result of this has been the conclusion which has at the same time become the basis of his own mutation theory—that by means of fluctuating variability certain local and improved races may indeed be bred, but that in nature new species never arise through its agency. These latter owe their origin exclusively to mutation, to 'discontinuous' variability. He is here entirely opposed to Wallace, who looked upon fluctuating variability as the real source from which species gradually originated.

With Darwin, de Vries is less at variance, and a quotation from the 'Origin of Species' leaves no doubt that Darwin fully appreciated the value of the single variations for the formation of new species. We read on page 66 of the edition of 1872:

In order that any great amount of modifications should be effected by a species, a variety when once formed must again perhaps after a long interval of time, vary or present individual differences of the same favorable nature as before; and then must again be preserved and so onward step by step.

These lines contain an abstract of de Vries's mutation theory. And then further, on page 72:

It should not, however, be overlooked that certain rather strongly marked variations, which no one would rank as mere individual differences, frequently occur owing to a similar organization being similarly acted on. . . . There can also be little doubt that the tendency to vary in the same manner has often been so strong that all the individuals of the same species have been similarly modified without the aid of any form of selection. Or only a third, fifth or tenth part of the individuals may have been thus affected, of which fact several instances could be given. For cases of this kind, if the variations were of a beneficial nature, the original form would soon be supplanted by the modified form, through the survival of the fittest.

Again, when Darwin denies having said that time alone plays a part in the process of modification which changes one species into another, he writes (p. 82, *l. c.*):

Lapse of time is only so far important, and its importance in this respect is great, that it gives a better chance of beneficial variations arising and of their being selected, accumulated and fixed.

In the fragments which I have quoted Darwin appears to have had before his mind mutation, not fluctuating variation. And I must insist on the fact that de Vries makes a point of showing that Darwin was decidedly inclined to accept the process of mutation. De Vries quotes (p. 25) from Darwin's 'Life and Letters' (p. 87, Vol. II.) and from the 'Origin of Species,' *e. g.*, the following words:

The formation of a . . . species I look at as almost wholly due to the selection of what may be incorrectly called *chance* variations . . . unless such occur, natural selection can do nothing, and he adds: It is obvious that Darwin has attributed a great and often a preponderating, perhaps even an exclusive significance to the single variations. . . .

The chance variations were not for Darwin the extreme cases of fluctuating variability, that can be everywhere observed; they were fortuitous phenomena. For these natural selection is always on the lookout, or as Darwin has it, metaphorically, 'He catches hold of them, whenever and wherever opportunity offers.' Darwin must have been inclined to think that these variations, these mutations, arise in accordance with certain laws which are entirely unknown to us. In consequence of the operation of these laws at least a certain number of favorable modifications must inevitably arise after a given lapse of time. Hence the gradual evolution which most living organisms have undergone in the course of ages.

Darwin also undoubtedly suspected the existence of a certain periodicity. 'Nascent species are more plastic,' he says; and he

thereby intends to imply that they form more numerous single variations and have thus a better opportunity to split up again into further species—so far de Vries (pp. 24–26).

I have purposely insisted on these points, because here and there a tendency seems to prevail to look upon Darwin's views on the origin of species as unsatisfactory and obsolete, and to proclaim the necessity of replacing them by a brand new hypothesis with which the name of de Vries should be coupled. These tendencies are in great favor with those that bear a grudge to the so-called Darwinism for other than scientific reasons, and who in their innermost heart would at the same time like to see a similar fate reserved for de Vries's demonstrations, and even for the whole theory of evolution.

We have, however, seen in de Vries's own words how little he considers himself an antagonist of Darwin. On the contrary, his great and imperishable merit consists in this, that his important and extensive experiments have provided us with a reliable basis concerning a subject about which Darwin had not fully made up his mind.

Darwin seems to have suspended his judgment; at all events, he has not drawn a hard and fast line between the results which artificial selection can attain when applied to fluctuating variations, on the one hand, and to mutations, on the other.

The experiments which de Vries has continued during many years on the two divergent processes, which Darwin has not sufficiently kept separate, have justified him in claiming that now, for the first time—forty years after the appearance of the 'Origin of Species'—the actual birth of a species has been observed by him. He has thus opened up a most extensive field for further investigations by other naturalists, and he has undoubtedly put an end to useless polemics which often threaten to become yet further burdened by subtleties.

Far from having undermined Darwin's Darwinism, de Vries has completed, purified and simplified it. To Wallace's Darwinism, however, de Vries has dealt a severe blow, Wallace having attached no significance to 'single variations' as possible sources of new species; whereas Darwin has always continued to acknowledge their importance as such, even though he did not thoroughly understand the laws to which fluctuating variability is subject. Even Weismann, who has only partially appreciated Darwin's philosophic indecision and who has, without wavering, followed a road which has now landed him in his 'germinal selection,' has undoubtedly taken notice of de Vries's experimental treatment of the subject with interest, though probably not with personal satisfaction.

Let us now try to picture to ourselves what conclusions de Vries has been able to reach experimentally with respect to the phenomena of mutation, and what he has taught us concerning the all-important question: How have species originated?

De Vries has started from the phenomenon above mentioned, so well known to nursery-gardeners and which is often of considerable financial importance to them; the phenomenon that suddenly in some of their flower-beds single variations appear which are constant when reproduced by seed. By systematically propagating these exceptional specimens a quantity of seed may be obtained in a few years that can be brought into the market. Soon, however, the variety loses its mercantile value; seed may now be obtained by anybody in increased quantities from the plants that have already been sold.

Are there any of our native species of plants in which the same phenomenon produces itself naturally? was the question which de Vries set himself. And if so, can they teach anything about the formation of species? In commencing the inquiry he started with about a hundred different species. Of all these, only one exhibited the property sought for—this, however, in such a way as to throw full light on the subject in most unexpected directions.

The species of plant which de Vries actually managed to detect in the act of 'mutation' on certain fields in Graveland, and which has continued to do so with perfect distinctness during many years in the Amsterdam Botanical Garden, bears the name of *Œnothera Lamarckiana.* It is one of three species of the genus that have been brought over from the United States and is now running wild in Europe.

De Vries has thus convinced himself that the great majority of plants about us do not show cases of 'chance variations,' 'mutation variation' *per saltum;* in other words, that the species that have been observed for many centuries may be said to be stable, invariable. But they are stable in so far only as—perhaps with very long pauses—periods of mutability appear, during which, next to the stable central species, new sub-species appear that are also stable when propagated by seed. Further experiments, however, are required to throw light on the periodicity.

Another conclusion was this, that the species which do produce *mutations* bring forth not a single mutation, but quite a number of them, varying among themselves. The mutations occur both in plants growing in the wild state and in those samples of *Œnothera Lamarckiana* that are bred under supervision. Their frequency, as determined by exact statistical tables drawn up by de Vries, varies between one and two per cent. Of the 50,000 *Œnothera* which de Vries has observed during ten years' culture, there were 800 that could not be designated by the name *Œnothera Lamarckiana.*

A somewhat skeptically disposed person may claim that this number of 800 indicates the number of the most marked deviations which were noticed among 50,000 plants; that, in other words, they are individual, fluctuating variations that would also be found in the same

quantity among 50,000 other plants. To this it may be replied that the phenomenon of fluctuating variation, as it appears in *Œnothera,* has been studied in detail by de Vries and has been exactly determined both for the central species and for the different subspecies (mutations). In all of them it occurs on a large scale, but not one of the specimens above mentioned belongs to it. These 800 have very special characteristics, by which they can be sharply distinguished from the fluctuating variations. And, as is especially remarkable, they are not in every respect different from each other, but may be arranged in seven natural groups, each of which possesses exactly the same systematic value as that particular combination of specific characteristics to which the name of *Œnothera Lamarckiana* has been applied.

The number of individuals of those seven groups, of which de Vries has observed the spontaneous appearance, is, however, most unequal and varies between 1 (*Œnothera gigas*), 56 (*Œnothera albida*), 350 (*Œnothera oblonga*), 32 (*Œnothera rubrinervis*), 150 (*Œnothera nanella*), 221 (*Œnothera lata*) and 8 (*Œnothera scintillans*).

De Vries has studied the mutations thus arising, some of which are rare and some more common, with the utmost care, and has followed them during the whole of their existence.

Œnothera gigas, which has only once arisen in the Lamarckiana group and which is characterized by much larger-sized flowers, a different shape of the leaves that form a rosette at the root, more thickly set leaves along the stem, etc., was sown by de Vries in 1897, after he had obtained seed, thanks to artificial fecundation, the possibility of self-fertilization being excluded. He thus obtained 450 plants, which, with the exception of a single one, exhibit all the characteristics of the *Œnothera gigas* with perfect constancy. The exception was not a retrogression towards *O. Lamarckiana,* but a new deviation, provisionally indicated as *O. gigas nanella.* From 1898 to 1900 further propagation by seed has been effected during three generations and under very strict precautions; and until now all the descendants of that one mutation of 1895 remain perfectly constant; de Vries has actually *seen* the species *O. gigas* come forth out of *O. Lamarckiana,* first in nature, afterwards in his own nursery-garden. It appears to be a very strong plant, which, if it had to fight for its existence against *O. Lamarckiana,* in equal numbers and under the same circumstances, would probably prove to be the winner.

The second mutation, *Œnothera albida,* which occurred 56 times during the experiments, shows another character. It is a feeble plant, and was originally considered a pathological deviation, which, however, in the later generations has proved itself to be none the less constant, and, though but little fertile, produced 86 plants in 1898 and 36 in 1899.

The third mutation, called *Œnothera oblonga,* repeatedly occurred (350 specimens) in the series of generations of *Œnothera Lamarckiana* that were successively cultivated. Many hundreds were cultivated later. It may be recognized with certainty as soon as the sixth leaflet unfolds, and has remained unchanged, with the exception of two specimens, which, however, have not retroceded towards *O. Lamarckiana,* but showed the characteristics of *O. albida* and *O. rubrinervis.* This mutation has thus, although perfectly stable, retained the power to further mutate.

The fourth mutation, *Œnothera rubrinervis,* again shows other interesting peculiarities. It is a strong plant, not less rich, both in pollen and in seed,* than *O. Lamarckiana,* which was more or less the case with the other mutations. It has been obtained in very great numbers (2,976 specimens) by de Vries, and the stability of *Œnothera rubrinervis* has asserted itself most distinctly also for all those specimens that had descended from different mother plants.

The fifth mutation, *O. nanella,* differs from the others in the fact that its deviation from the original *O. Lamarckiana* does not show itself in a given number of sharply determined and constant characteristics, but only in one, its dwarfed dimensions. Thus we should be inclined to look upon *O. nanella* rather as a variety than as an elementary species. However, in this case the smaller dimensions do not come under the head of fluctuating variability, but we have undoubtedly an unmistakable mutation that can be recognized as such with certainty as soon as the second leaf begins to show itself, and which, when fecundated in 1893 by its own pollen, directly produced 440, and in 1895 2,463 germinating plants, all of them, without exception, *Œnothera nanella.* In 1896 the seeds of 36 other plants of *O. nanella* were again planted and 18,000 seedlings were obtained, which again showed, with perfect precision, the characteristics of the species, with the exception of three mutating plants that bore at the same time the distinctive characters of *O. oblonga,* and thus formed an elementary species of the second degree, *O. nanella oblonga.*

We have yet to mention two mutations, *O. lata* and *O. scintillans.* The first only consists of female plants; there is never any fertile pollen produced, so that its stability can not be made out with certainty. The second, a dark green plant with shining leaves, is a rare mutation.

* It should here be mentioned that de Vries has noticed (*l. c.*, p. 186) that the seeds of mutating plants generally retain the power of germinating for a longer period than the seeds of the normal *O. Lamarckiana.* Upon this fact he bases the expectation that perhaps later it will be possible to utilize this peculiarity and to find means to increase the percentage of mutating plants in a given series of sowing experiments by artificially somewhat accelerating the dying off of the seeds. This might also prove important when searching for mutations.

which especially differs from those we have been studying, by the fact that even when artificially fertilized, with the utmost precautions, the mutation is not stable. The majority of its descendants belong to three groups: *O. scintillans, O. oblonga, O. Lamarckiana.* As compared with the wonderful stability which we encountered in the preceding mutations, the lability of this one—which at the same time seems to follow a certain law—is a most remarkable phenomenon, the origin and the significance of which have still to be traced.

We have now seen that for a number of years de Vries has been able, by his careful and skilful experiments, actually to witness the very process of the origin of species in nature. On the particular spot near Graveland, where he first noticed the process of mutation in nature, it had, of course, been going on even before his first observations. He here encountered, besides the *O. Lamarckiana,* a second species, the *O. lævifolia,* with which he also made experiments in the Amsterdam hortus, and which also produced numerous mutations, some of them identical with those obtained from *O. Lamarckiana.*

Especially important was the irrefutable demonstration of the fact that the process of mutation does not appear as one single specimen which gives rise to a constant variety, but that it again and again repeats itself in every generation in a certain percentage, and that absolutely the same 'mutants' appear—even though in varying quantities. The individual mutants thus find their chance of surviving considerably increased and, as soon as a slight change in the outward circumstances occurs, any mutation, which at the outset was in the minority as compared with the parent species, may slowly but surely become the majority. It is constantly getting a fresh supply from the parent species and, as soon as it shows itself better adapted to the circumstances, it may finally supplant the parent species entirely.

This struggle for existence does not occur between individuals of the same species, but between the mutations and the parent species. As long as the mutation has not appeared, there can be no question of the origin of a new species; the species is then constant, and only submitted to fluctuating variability, which can produce local races (not elementary species) under the constant cooperation (either artificial or natural) of selection, but which never leads to the formation of species. During a period of mutation a modification of the species is not always a necessary consequence; for in many cases the parent species will prove to be the fittest, and the mutations will then none of them be permanent.

The fact has been established by de Vries that in the natural life of a wild plant a series of phenomena occurs which justifies us in saying that he has made us see and actually touch the origin of species, whereas Darwin had made us understand it.

De Vries has not deviated from the teachings of the master, but he has developed them; he has brought us a further and a most important step forward and he has paved the way for later investigators. Theirs will be the task to make out in how far the laws of the mutation process, which de Vries has for the present only been able to make out for one genus of plants, also apply to the other plants and to animals. These laws are: (1) New elementary species arise suddenly, without transitions. (2) New elementary species are generally perfectly stable from the very first. (3) Most of the new types have all the qualities of elementary species, not of varieties.* (4) The elementary species usually appear in a considerable number of individuals simultaneously, or at least within the same period. (5) No important relation whatever exists between individual variability and the new qualities of the elementary species. (6) The mutations, which give rise to new elementary species, take place in the most various and divergent directions. The modifications concern all the organs and are of the most varied descriptions. Part of the new types perish without descendants. Among the others, natural selection must slowly decide. (7) The phenomenon of mutability appears periodically.

Some of these laws of the mutation theory require further explanation. In the first, the *sudden* appearance of new elementary species is formulated. The characteristic qualities of the species thus arise *per saltum,* without transitions, such as are always observed in fluctuating variations. The ancestral forms of the different *Œnothera* 'mutantes' were perfectly well known. It is a fact that every mutant has been obtained from seed of normal and carefully examined *O. Lamarckiana.* On every occasion the new mutation suddenly appeared in all its details. The name 'elementary species' is given to the new form, and here we enter the domain of terminology and must necessarily furnish some explanation.

What is a species, what is a new species? What is an elementary species, which has also been called a subspecies? Are these last different from races and varieties? If so, how? For those who are not naturalists all these questions seem to be frivolous. They know that Darwin has written a celebrated work on the 'Origin of Species' and that a century earlier Linnæus had instituted for species in nature the 'binary nomenclature,' so that *'Bellis perennis'* stands for daisy, *Elephas indicus* for the Asiatic, and *Elephas africanus* for the African elephant. And so, according to their lights, zoologists and botanists will, by this time, have agreed on what a species is. This, alas, is far from being the case! The Mosaic belief in the separate and inde-

* "Many of my readers," says de Vries, "will be inclined to call my new species varieties, *just because I was able to trace their origin.* This is a mere verbal contention, of no importance at all for science."

pendent creation of every species at least furnished us with a distinct definition, even though transcendental. But as the idea of a slow and gradual evolution in nature has come to predominate in the course of time, sharp boundary lines have been effaced, and species have become both of an artificial and of a temporary nature. They have become a compartment into which man temporarily brings together a larger or smaller number of individuals, knowing that in times gone by the contents were confluent with those of another such compartment and that in the far future there will be other changes.

And when in later years the ideas of Wallace, which we mentioned above, found increasing sympathy, the lines of separation grew dimmer yet, and the idea of species became exclusively an artificial limit comparable in musical terms to so many thin lines that mark the bars in the continuous symphony of the evolution of life upon earth.

Thanks to de Vries's experiments, which have enabled him to formulate his mutation theory, he has now provided us with the means to define species more strictly. The species is limited by space and time. By time, for it begins whenever, by a process of mutation, its peculiar combination of specific characters springs into existence, even though this mutation, unobserved by the untrained eye, can as yet only be detected by the specialist. Whenever mutation appears, the combination of specific characters is modified in the mutants, and at the same time a new species has appeared side by side with the mother species, which itself remains stable.

The distribution of a species in space can be very varied; some are known only from a very limited area, others may be cosmopolitan. The species thus limited in time and space is what de Vries calls an elementary species. It is with these elementary species that the next generation of naturalists will have to grapple when they wish to elucidate evolutionary problems experimentally. The existence of such elementary species is no novelty which de Vries has been the first to make us acquainted with. Linnæus knew these elementary species perfectly well, but he called them varieties and forbade his pupils to waste their time on them. 'Varietates levissimas non curat botanicus.' From his point of view this was perfectly justified. He came forward to restore order in the chaos of classification, and as such he strove to combine the material then available into not too small bundles. His species were what the Germans have called by an expressive name 'Sammelarten,' receptacles, into which the so-called 'varietates minores' were thrown together. According to his idea, the species had been created in the beginning as an entity, the 'varietates' had gradually arisen from it, even though he could not prove this experimentally. With regard to them, Linnæus was an evolutionist, just as, among his predecessors, the idea had long predominated that the genera had been

created, whereas the species had come from these, as so many local deviations.

Who would deny that Linnæus's work has facilitated the task of those that have come after him? Nevertheless, many species have been repeatedly subdivided. We must henceforth admit that when a species goes through a period of mutation, or has just gone through it, the number of elementary species that keep up their independent existence by the side of the parent species may be considerable, as we have seen with *Œnothera*. And it is easily understood that a tendency arises to denominate for convenience those numerous elementary species not by their own names, but by a collective name. This happens in most handbooks of systematic botany for well-known European plants, as, *e. g., Draba verna,* of which not less than 200 perfectly stable elementary species are known, *Viola tricolor,* etc.

Henceforth, however, we may no longer allow ourselves to be guided by opportunism. Systematic botany will have to take her watchword from physiology. De Vries has combined the qualities of the experimenter, who dares to look the physiological problem in the face, with those of the systematist, who observes and appreciates with uncommon sagacity the slightest shades of difference, and who with utmost delicacy of touch sifts and deals with species and races, mutations and variations.

The elementary species are stable. Selection calls forth different races within the limits of these species, but whenever selection ceases the races turn back to the parent form. The maximum deviation in these races is generally obtained after three or four generations of continuous selection; it takes about as many generations to bring back the parent form.

It is superfluous to say that many of these phenomena must be yet submitted to experimental investigation. De Vries has started this, and both in the domain of fluctuating variation and formation of races and in that of crossing and hybridizing he has already partly completed, partly only just commenced, elaborate experiments. Others besides himself have of late years analyzed the phenomenon of variety closely. The Cambridge zoologist, Bateson, has attempted to trace in his well-known work, 'Materials for the Study of Variation,' *what* it really is that variability offers towards the making of species, both in the most different species of animals and with respect to their divergent organs. He has, however, not seen his way out of the labyrinth, and although he came to the conclusion that it is not fluctuating variability which presides over the formation of species, but that a *discontinuity* must necessarily play a part, yet he, too, has committed himself to the assumption that the determination of the width of the fluctuations can furnish us with valuable data for understanding the gradual forma-

tion of species. He, too has not yet succeeded in analyzing and distinguishing from each other—what has been de Vries's merit—variability within the boundaries of constant species and mutability which does not fluctuate, but which by a sudden bound leads to the new species.

Much closer to this valuable discovery we find two students of the fossil-animal kingdom, two paleontologists, one of whom (Waagen), as long as twenty-five years ago, understood the importance of the phenomenon of mutation, even without the support which the series of de Vries's experiments would, of course, have afforded him, while the second (W. B. Scott, of Princeton) has most clearly expressed himself (*American Journal of Science,* 1894) that the formation of species by selection of fluctuating mutations, such as Wallace maintains, is rendered most improbable by what the fossil-animal world teaches us.

This world of fossil animals exhibits in certain regions of the earth, where the successive geological formations have been retained in undisturbed order, a similarly undisturbed ascending series. Far from finding in that series the divergent fluctuations which Bateson had accepted for so many animals, Scott has shown (and has strengthened his argument by referring to the results of many other paleontologists) that these fluctuations are indeed—though exceptionally—found among fossil animals as so many individual deviations (thus proving that also in that time the fluctuating variability existed within the limits of the species)—but he is at the same time convinced that this phenomenon has nothing to do with the slow modification of species, which takes a straight line and not a zigzag one.

Scott, although he was not at that time acquainted with de Vries's experimental evidence, staunchly holds to the idea that species have not grown out of the gradual selection of deviating individuals, but have appeared by mutation, by very small but sudden starts from one stage to the next.

We see before our eyes how the species of the deeper layers are gradually modified as we reach the higher layers; we find that all individuals simultaneously underwent this modification; in other terms, the phenomenon can hardly be described otherwise than by saying that the older species tends directly towards an aim, which the younger species that has descended from it has attained.

Many paleontologists even go so far as to admit a previously determined direction in gradual evolution. There is, of course, close affinity between such a predetermined direction in evolution and the teleological idea of design presiding at the creation of species. Clerical opponents of evolution may here have their chance of adapting the newest results in the study of that process to their personal principles.

Still, although the mutation experiments of de Vries have considerably strengthened the argument of Scott and other paleontologists, that slow, simultaneous mutation has also taken place among those fossil animals—the same experiments have, moreover, proved beyond any doubt that there is no such thing in nature as predetermined mutation in one special direction, but that, on the contrary, mutation occurs in very different and very divergent directions.

When once the mutation process leading to the formation of species has begun, the most different mutations, as we have seen above, arise. From our point of view, some of these may be called good, others bad or indifferent. About the permanence of any of them, it is, however, the surrounding conditions, acting by means of selection, that decide. And often the decision lies in another direction than would have been surmised from the human adjectives just named.

By the phenomenon of mutation the possibility exists that useless, and even to a certain extent prejudicial or noxious, specific characters may appear, a phenomenon which could never be reconciled with the views of Wallace.

For the greater part these characters are sure to be eliminated, but if other circumstances happen to be or to become favorable to a mutation, which was originally without any particular significance, it can then gradually develop and become adapted to certain modifications in the surrounding factors of life. The majority of the mutations, however, soon perish in the struggle for existence. Of those many elementary species that were doomed from the first, nothing has, of course, come down to us in the archives of the fossil remains; only when their number has considerably increased in comparison with the parent species will it have been possible for them to survive, but then they have already risen to be a side branch, or may even be supplanting the parent stock.

The theory of mutation, as well as that which ascribes the origin of species to the selection of fluctuating varieties, enables us to understand how efficiency and adaptation in organic nature have come about by the mutual interaction of natural processes without the aid of supernatural intervention. The struggle for existence between species and mutations comes about in the same way as does the struggle for existence between individuals in the older view. Spencer's expression, however, 'the survival of the fittest,' must henceforth be interpreted as meaning 'the survival of the fittest species.' When we agree with de Vries that the gradual mutation of species is not necessarily the revelation of a foreordained design, this should be interpreted in the spirit of greater humility which befits the naturalist when he is confronted by the gigantic problems of organic nature. As long as a natural coordination of facts furnishes us with an intelligible causal

connection, he does not feel justified in agreeing with those who are ready to accept explanations outside the pale of science. The same naturalist, however, will always be found ready to admit that he is yet exceedingly far from being able to give an 'explanation' of the inner meaning of the real significance of the mutation process.

In order to penetrate into this it is necessary to analyze further the phenomenon of heredity. Concerning this, de Vries has already on a previous occasion published theoretical views which follow in the footsteps of Darwin's celebrated theory of pangenesis. As the chemist operates with molecules and atoms, for the reconstruction of the processes of inorganic nature, so the biologist, when trying to represent to himself living matter, has to take into account the smallest entities, which have received various names from various naturalists, and to which de Vries gives that of 'pangens.'*

Pangens are something different from complicated molecules; they can assimilate and they can reproduce themselves. Not only does all living matter, wherever found, consist of them, but those smallest living particles must at the same time be considered, either individually or grouped together, as being bearers of single or of mutually correlated properties of living matter.

An augmentation or a diminution of the number of pangens which represent a certain property will call forth the phenomenon which we have named fluctuating variations; while a modification in the composition of the pangen, for example, by division in two unequal parts, or by substitution—using a term well known in chemistry—will be equivalent to a mutation (progressive mutation), as will also the disappearance of a determined pangen (regressive mutation). Thus, according to these abstract representations which we form of the mysteries of heredity, the fluctuating variation depends on quite a different category of phenomena from those of the chance variation. And we understand directly that the chance variation obeys a more complicated mechanism than fluctuating variation, which depends only on the greater or lesser numerical importance of the preexisting elements, while the chance variation, the formation of species, implies a change of the existent elements.

As to how this change in the pangens periodically takes place, both simultaneously and successively, among a certain number of individuals, or might be aroused or caused; as to how the unequal division or substitution obeys fixed laws in such a way that the mutants, arranged in groups, are alike—all this for the present can not be explained by us.

If we aim to understand the conditions we shall be able to create species, as we can now breed improved races. And as we gradually

* H. de Vries, 'Intracelluläre Pangenesis,' Jena, 1880.

learn to analyze the elements of the phenomenon, the probability grows that sometime we shall master the art of actually directing the series of natural phenomena. A new and limitless field of work would then be opened. Provisionally we can guess only from what we have as yet observed that certain processes are able to call forth or to accelerate the phenomena of mutation. Thus de Vries suggests the idea that a rapid succession of periods of reproduction might facilitate the reappearance of a period of mutation, whilst others think that transportation into quite different surroundings or transplantation might produce it. Others, again, appear to believe that increased nutrition, either combined with the conditions mentioned or not, would call forth mutation. All this, however, is no more than guesswork and hypothesis. We have as yet no means of fully knowing and of understanding.

For the present it is safer to recognize our absolute ignorance, and at the same time to define more exactly how far de Vries has brought us, and what is the important step for which we have to thank him. We can warmly recommend the reading and studying of de Vries's clearly written and beautiful book. He has been the first to show us the sharp distinction that exists between chance variation and fluctuating variation, and to prove that it is not the latter, but the former, that calls forth in nature the origin of species. He has not yet been able to tell us whether, and, if so, how, chance variation could be called forth artificially by man. The fact that artificial selection of fluctuating varieties, as well as hybridizing, etc., has already led to such indisputable improvements in the different races of animals and plants may, however, give us hope that a conscientious experimenter and close observer, such as de Vries, has still a full store of important pioneer's work before him and may yet succeed in finding how to direct the mutation process. Thus, the origin of species would not only have been studied more closely, but would be subjugated to the human will. After having seen species originate in nature, man would then be able to call them forth. Then only the 'Origin of Species,' to which Darwin has given us such a marvelous introduction, would be revealed in all its details.

THE IMMIGRANT, PAST AND PRESENT.

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AFTER the Peace of Paris in 1783, and the birth of a new nation on the American continent, home-seekers arriving at ports of the United States were called immigrants. Previous to the revolutionary war they were known as colonists. The distinction is one of political allegiance. The colonist was an immigrant who desired to make a home in the new country, but to retain his allegiance to his native land. On the other hand, the immigrant, in a majority of instances, expected and desired to change his political allegiance. Even at the present time the government of Italy regards as Italian colonists all Italians in America who have not been naturalized. If we except the question of political allegiance there was little difference between the colonist and the early immigrant. There were no large centers of population such as exist to-day to invite the parasitic class, nor were there large factories, mines or mills, to demand a supply of unskilled laborers. The country, except a narrow strip along the Atlantic seaboard, stretched in an almost unbroken wilderness far to the west. The type of immigrant willing and able to brave the dangers and hardships of the new country, and hew out a home in the heart of the forest, was necessarily brave of heart, and strong of hand, the very best type of an immigrant—the pioneer. The immigrant of those days was not allured by the promise of high wages, nor by the desire to better his financial condition, but was actuated chiefly by the desire to create a home, and free himself from the trammels and persecutions of the old world. He was at once a pioneer, a woodsman and a farmer. He left behind him many evils, coercion, compulsory military service, religious or racial persecution, grinding taxation, wars in which he had no interest, and prohibitive systems of land tenure. He found in this country, land for all, absolute freedom from racial or religious persecution, personal liberty, and respect for the rights of the individual, regardless of social position. The many advantages offered to the home-seeker who was brave, willing and strong, in the new United States, attracted many thousand immigrants, and it is estimated that one hundred and fifty thousand settled in the country between 1783 and 1810. These early immigrants were mostly from the British Isles, with a few Germans, French and Scandinavians.

The strained relations with England followed by the war of 1812, practically stopped immigration for several years. During 1817, however, twenty thousand immigrants arrived in the United States. This number was unprecedented at that time, and caused considerable criticism of the overcrowding of immigrant ships.

Immigration first assumed large proportions during the decade 1831–1840. It increased progressively, and during the next twenty years was relatively greater in proportion to the native population than at any other period. The great famine in Ireland greatly increased Irish immigration. German immigration was increased at the same time because of industrial depression and the revolt of 1848. The discovery of gold in California, no doubt, also contributed to the increase of immigration at this time.

Irish immigration reached its height in the decade 1841–1850, when it constituted 46 per cent. of the total. It has declined steadily and is now only 4 per cent. of our total.

The Germans kept coming in increasing numbers and in the early eighties were 30 per cent. of the total. They also have fallen off, and now constitute less than 10 per cent. The Scandinavians became a considerable factor in the decade 1861–1870, and in 1889 furnished 10 per cent. of our immigrants. Their proportion has also declined and at present is about 10 per cent. With the decline in the proportion of immigrants from the United Kingdom, Germany and the Scandinavian countries, a rapid increase in the arrivals from Italy, Austria-Hungary and Russia is noticeable.

This marked change in the complexion of immigration can be appreciated from the fact that in 1875 we received 3,631 from Italy, 7,658 from Austria-Hungary and 8,981 from Russia, while in 1903 we received 230,622 from Italy, 206,001 from Austria-Hungary and 136,093 from Russia. In other words, the immigration from these countries to 1875 was only 9 per cent., while to-day it constitutes about 67 per cent. of our total immigration.

In general, the immigrant of the past differed greatly from the immigrant of to-day. As has been stated, the first immigrants were pioneers and differed little from the old colonists of pre-revolutionary times. As time went on they spread from the Alleghenies to the Mississippi, side by side with pioneers from the New England and Southern states. These immigrants were agricultural in occupation and were invariably home-seekers.

The development of our vast natural resources, particularly coal and iron, created a demand for a new type of immigrant, an unskilled laborer, who may be styled an industrial immigrant. The building of the great transcontinental and other lines of railroads furnished additional work for this industrial immigrant, and opened up vast new

fields hitherto inaccessible to agricultural home-seekers. Of late years, most of the desirable, arable land, profitable and fertile without irrigation, has been taken up, and the advantages offered the agricultural type of immigrant in the west have been materially lessened, but our wonderful industrial growth still demands and attracts the strong willing unskilled laborer, and this demand will probably last for many years to come.

The development of our great manufacturing industries also attracted great numbers of skilled artisans and mechanics. At first these skilled laborers were necessary. The necessity for their coming has now disappeared, and not only are they unnecessary for development or progress along industrial lines, but they enter into direct competition with American mechanics and artisans. These may be classed as competitive immigrants.

The rapid growth of our large cities, the establishment of great centers of population, most marked in the past twenty-five years, attracted another class of immigrants, who can only live in such environment, who are simply human parasites unable to exist by their own effort.

Thus immigrants of to-day can be grouped under four heads, (1) agricultural, (2) industrial, (3) competitive, (4) parasitic. The agricultural class includes farm laborers and those desiring to take up land for settlement. The industrial class includes the great army of unskilled laborers, who seek employment in the mines, mills, great works of construction and manufacturing concerns. These two classes are valuable and necessary for the development and industrial progress of the country. The competitive class takes in the skilled laborers, mechanics, artisans and others who come here and enter into competition, in their respective callings, with Americans. This class is not necessary for our advancement and may or may not be of value to the country. The fourth or parasitic class is, as its name implies, not only valueless, but decidedly detrimental to the body politic. In this class are included the peddlers, fakirs, paupers, etc., who congregate and will live only in the large centers of population and who can not or will not do hard physical labor. This class constitutes a load to be carried, and their deleterious influence on the vigor of the nation is in direct proportion to their numbers.

Social and political conditions in Europe determine to a large extent both the quantity and the quality of our immigration. A country well and justly governed and which is in a prosperous condition is not likely to send us many good immigrants. The type of Englishman who would be welcome here as an immigrant, the sturdy Anglo-Saxon yeoman, of whom we delight to form a mental picture, finds conditions of life so suited to him in England that we rarely see him as an

immigrant, and we are much more likely to receive as our English immigrant the degenerate product of the East London slums. The same has been true of Germany for many years, the prosperity of the country, the growth of national pride and reconciliation to the form of government have cut down the German emigration from the great exodus of the eighties to the comparatively insignificant figures of to-day; and the German immigrants to-day do not compare favorably with their countrymen who came here twenty-five years ago. It will be seen, therefore, that it is unwise to consider an immigrant good because he is of one race, or worthless because he is of another. They must be measured individually irrespective of race or creed, for it is better to receive the robust pastoral or agricultural immigrants from countries where the intellectual status, perhaps, is not high and the school system faulty, than to receive from countries, possessing a high intellectual status and a superior educational system, the urban degenerate, criminal, diseased and defective.

To-day we receive the agricultural home-seeker as in the early days of this country. We demand and receive the industrial immigrant, the unskilled laborer who was unknown as a type fifty years ago. And we also receive against our own will the human parasite who remains and can only exist in the great centers of population.

The work which will be done in the next twenty years to reclaim the arid land by irrigation will be genuine empire building and provide thousands of homes for agricultural settlers. No doubt proper care will be exercised by the government to prevent this reclaimed land from falling into the hands of speculators, and the bulk of it will be available for the immigrant of the future.

WHY IS THE HUMAN EAR IMMOBILE?

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THE ear has had a varied history. The evolutionist has a remarkable story to tell when he recounts the steps in the making of this organ. He traces the opening of the ear to the gill-slits of the fish forms of whose lineage we are. He shows (though this subject concerns us less at present, and is still discussed with some uncertainty as to details) how various structures in the region of this opening, which had originally a different purpose, were modified to become the series of little bones that propagate the vibrations of the air from the tympanic membrane to the fluid of the inner ear. He shows further, with greater or less completeness, how the cartilage shell grew on the outer side of the head, and was supplied with muscles, so that it could be moved about and even have its shape changed.

To get a good illustration of the mobile ear we only need to watch such an animal as the horse; the ear is as mobile as the eye, or more so. The poet speaks of the horse's ear and eye as twinned; but it is interesting to notice that each of the horse's ears can work independently. And it is evident that nature at one time meant, so to speak, that man's progenitors should possess ears of similar mobility. She gave them the projecting frame of cartilage and she attached to it the muscles for its movement. Then in the course of the generations she changed her mind and withdrew what she had bestowed. The cartilage shell, curiously wrought, is still there, and we regard it as adding to the beauty of the head; yet it is probably only a rudiment. The tip of the ear, when present, is a small outgrowth on the outer fold of the cartilage and is turned towards the center of the ear. The muscles of the ear, seven in number, are also rudimentary. Occasionally an individual is found who can move his ears; but even these movements are generally of an abortive kind, and are so unusual that the sight of them may distress those who are sensitive.

Why has man lost this power? Is it simply a case of retrogression? Or is it a loss for the sake of a greater gain, possible only through it? I think the reasons for this change in the organism can be indicated; one can, at least, point with assurance to a great mental gain in which it has resulted.

It will prove helpful to an appreciation of this gain to inquire first what man has lost in the passing of this mobility. The signifi-

cance of this loss can be better understood if we consider for a little such a sense as sight.

The eye is movable and is continually shifting its position. From this mobility two results follow which in the present connection it is important to notice. First, the eye can be readily turned so as to get the clearest vision of any object that is to be examined. We do not see equally well with all parts of the eye; we see most distinctly with the central part directly opposite the pupil, and when there is anything seen out of the corner of the eye which we wish to observe more closely, the eye is, in normal circumstances, turned upon it so as to catch the image in this central part. Spontaneously and accurately these changes in the eye's direction are made. It can readily be understood that great help to our perception is gained from them.

There is another result of this free movement which is of equal importance. To it is due the orderly spatial arrangement presented by the world of our vision. It may seem that our knowledge of the position of things in relation to each other is natural or instinctive, and we may be pointed to the behavior of many animals which are able to guide their movements correctly as soon as they enter the world. But such reflex activities do not seem to be strictly parallel to those of the human child. That the child has in its nervous system inherited a predisposition to its future adjustments, may be true. But it is also true that it does not respond to its surroundings as the chick, for instance, does; it gains its conscious appreciation of external relations by experience. What the child's first experience of sight is, it is difficult for the adult to guess; yet some of our perceptions approach to it. The German psychologist Volkmann von Volkmar calls attention to the fact that when we gaze into the blue depths of the sky our color perception has a character similar to that of a musical note. Probably our visual sensations are all, in their original intrinsic nature, of this sort; color feelings with no idea of position as yet developed. It is further to be noted that we might have a succession of color pictures, such as can be afforded by familiar mechanical devices, without any suggestion as to the spatial relations of these various pictures. And were the eye incapable of movement of any kind, its experiences would be a mere succession of vaguely voluminous color-feelings. But, on the other hand, let the eye be considered as capable of movement, and as free to play among these colors; it passes, say, from the image of the door to that of the wall, and then to that of the window. It is not less important to notice that it can by its power of movement reverse the series and pass from window to door. Such series may, to an indefinite extent, be increased, repeated, reversed. Thus the mind gets the idea of a series of images relatively permanent, always open to observation, and arranged in a perfectly

definite order. It is thus by virtue of the eye's movements that there is secured the perception of the orderly spatial arrangement of the world revealed to our vision.

Further evidence of the important functions which the eye's movements fulfill in perception might be adduced, but it is not desirable for the purpose in hand to take up what is more complicated and debatable. What has been said may suffice to call attention to the great significance of the mobility of the sense organ.

Evidence not less striking might be brought forward in regard to the sense of touch; it might be shown that it is by the movement of the sense organ, say, the finger tips, that explorations of the body under investigation can be, in ordinary cases, best accomplished, and that it is by the producing and reversing of series of touch sensations that the spatial relations of tangible objects are clearly recognized.

The ear is immobile. Accordingly it is incapable of reflex movements for catching sounds, like those by which the eye is turned so quickly to meet the light coming from an object.

We find likewise that the perception of space by means of sound is in an extremely undeveloped form. Many have gone so far as to deny that sound has any spatial character. Yet surely this view can not be maintained. We locate sounds to the right or left, behind or in front; moreover, we distinguish sounds as differing in volume.

Yet it can readily be seen that the spatial characters of sound do not compare in precision and definiteness with those of the sensations of color and touch. What is the size of the thunder? The question at first seems absurd. Yet it can not be entirely absurd, for we speak of the peal as heaven-filling. The appearance of absurdity is due to the hopeless vagueness of the sound image in respect to extent.

If we analyze this vagueness we find that owing to the immobility of the ear we can not locate sounds with precision. All are familiar with the difficulty of telling, especially in strange surroundings, whence a sound comes, unless the eye gives its help. The ringing of the bell of an unseen bicycle may cause us the most painful perplexity till we can learn its source by sight. Psychological experiments show in detail how untrustworthy are our attempts to localize sounds. Not that they are entirely untrustworthy. It may be that sounds have a special quality according to the direction from which they come and the way in which they strike upon the external ear; and recognition of this quality may give help towards their localization. But at the best, we are not freed from manifold confusions and errors. Thus it is found by experiment that while the change of position of the sounding body may be soon noticed, the direction of the change may be thought to be the opposite of what it is in reality. Again, relatively loud sounds are located preferably in front of the head, even when their source is

behind.* It can thus be seen that in accuracy of localization the ear can not be compared with the eye. The loss of the reflex apparatus by which the ear turned so as to catch most readily the vibrations in the air, has brought it about that the positions of sound are now so imperfectly apprehended by us.

The loss of this power of localization means two disadvantages. The first may be indicated in the words of Darwin:† "The power of erecting and directing the shell of the ears to the various points of the compass is no doubt of the highest service to many animals, as they thus perceive the direction of danger."

Closely connected with this practical disadvantage is another. The space of the ear has not the geometrical character of the spaces of sight and touch. Yet there is surely no good reason for doubting that it might have had much more of this character. Were the ear as mobile as the eye or the fingers, it would resemble them in the orderliness and well-defined character of the spatial forms it would yield. That its spatial form would equal in these respects that of the eye, it would be too much to affirm dogmatically. There may be more conditions to supply than merely that of mobility. Yet the touches from the less mobile parts of the body are singularly vague in their spatial outline as compared with those from the fingers and the tongue. And were the ear to gain mobility, we might expect to find it at least approximating, in its appreciation of form, to the senses which are regarded as so preeminently geometrical.

It is now apparent how serious are the disadvantages involved in the ear's immobility. Darwin thinks that the loss of the ear's movements is partly compensated by the increased ability to move the head about. It is true, these movements of the head are of importance both in seeing and in hearing. Yet in speaking of them as making up for the mobility of the sense-organs, we should be careful not to exaggerate their value. A man whose legs have been smitten with paralysis must find only small compensation for his affliction in the fact that a strong though somewhat slow porter is, when not otherwise occupied, ready to carry him about. It is also to be noticed that the eye has at its disposal the head movements, yet has retained its mobility.

We have now to ask what the mental gain is which has resulted from this loss. It is to be found in the ability to attend to a *succession* of sounds.

Let us notice how distinct is our perception of succession. A sound comes suddenly and sharply, and then it is gone, and another sound

* On the localization of sound, see 'Studies in Space Perception,' by A. H. Pierce.

† 'Descent of Man,' p. 14.

of distinct quality takes its place; thus by its very nature sound lends itself easily to this kind of perception. And when we listen to a sounding object, our interest is in catching the sounds which come in sequence. This is illustrated most distinctly, as we shall see, in attention to discourse. We hear simultaneous sounds, but the predominant characteristic of our perception of sounds is that their variety is given in a succession. Hearing is a time-sense. If the ear had remained mobile, it would have been the organ of a space-sense, for it would have given a number of sounds as practically coexisting and as coexisting in definite relations to each other; the mobility being lost, hearing has become a time-sense.

Contrast with the ear's perceptions those of the eye. We look at an object, and so long as we look, its form may remain the same. It may seem to be the same if we look at it after a day, or a month, or a decade. The great framework of our environment seems to the eye unchangeable.

It is not to be overlooked that we do perceive changes with the eye. We may watch a cloud melt in the summer sky, or we may call up the image of one who no longer lives. The eye can not ignore the fact of change, as the ear can not entirely ignore coexistence. And it is possible for us to school ourselves to note the changes from hour to hour in what we see. Yet the lesson is not naturally learned by the eye; its world is primarily a spatial world; its interest is in forms and the relations of these forms; for it succession is subordinate, as for the ear coexistence is subordinate. And as far as possible our idea of the stability of forms determines our interpretation of the changes we see. We watch a man walking along the street, or the trees waving in the wind. In such cases we see a change, but our mental reading of it is that a part of the spatial picture has been transferred from one point to another without any alteration in the intrinsic nature of the whole or the parts. It is possible that it is under the influence of the visual imagination that science keeps so persistently to the view that atoms shift their places, but do not suffer change. However this may be, the visual images of objects are spatial and in a measure stable; and they owe this peculiarity largely to the fact that the eye flashes from point to point and considers the external relations of figures to each other, to the comparative neglect of other aspects of reality.

On the other hand, the immobility of the ear contributes to the perception of succession inasmuch as the mind, being unable to get in simultaneity, or what is practically such, all the sounds of the environment, finds it easier to attend to the series of sounds. If nature had intended to cultivate the power of attending to a successive series of sensations, would not her first steps have been to make the organ

of these sensations stationary? Suppose the eye were to be trained to give special attention to the changes in objects before it, it would be essential that it should be prevented from making its usual excursions round the field open to it, and should be kept looking fixedly at one object. Not that this fixedness involves of necessity the inability to perceive a multiplicity of coexisting objects; it is found by experiment that when the eye is perfectly steady any one of the many points exposed to it can be attended to; and moreover, the attention can be directed from point to point. In hearing, too, we know that we can while remaining motionless, listen first to the sound from one quarter, then to that from another. But this only shows that when the natural instruments for performing certain acts are withdrawn from us, we may make shift to supply their places. We can see an object with the periphery of the eye, but we can not see it so well as when we freely turn the fovea upon it. And though we can direct our listening power from one point of the compass to another it remains true that the ear, smitten with immobility, can best fulfil its perceptive function when there is attention to the successive stimulations forming from one object.

It may seem that we have forgotten that such a sense as smell has an immobile organ, yet does not yield any special perception of succession. It is to be noted, however, that this sense is little developed in its perceptive aspect. We can not get the large number of discrete sensations from this sense that we can from hearing. We may by the ear distinguish five hundred sounds in the second. There is nothing in smell comparable to this. We need not wait to consider whether in its own undeveloped way smell does not after all remotely resemble hearing in the kind of perception it yields.

But we have not yet indicated the special forms assumed by the succession of sounds which it is so important to perceive. They are two—*language* and *music*. Language consists of a succession of sounds. When we consider how largely the intellectual life depends on language, we can see the enormous advantage of the development of the faculty of perceiving successive rather than simultaneous sounds. As every one is familiar with the importance of language, the greatness of the gain needs no further emphasis. Of less importance, though its significance for primeval man may yet prove to have been very great, is the appreciation of music. The music that is referred to is that given in melody. There is, apart from the melody, an appeal of each note and complex of notes which does not mean succession at all. Much of the thrill of music is an immediate effect of the individual note. But the appreciation of melody depends on the perception of succession. The eye is appealed to by a spatial combination of colors, the ear by a series of sounds. Readers of Lessing's *Laocoon* know how

finely he has elaborated the contrast between the esthetic characters of the two senses.

What, it will be asked, of the lower animals that have no external ear, or have one that can not be moved? In regard to such, we must carefully distinguish those species which have never possessed the movable ear from those which have lost the power of movement. It is the loss of a faculty once possessed that we are at present more immediately concerned with. Yet, in the case of such animals as the birds, which, though endowed with a highly developed sense of hearing, have no external ear, it is interesting to observe that there is remarkable appreciation of music. And this is not merely a response to individual sounds, as the musical appreciation of some animals may be; there seems to be an enjoyment of melody. Browning happily described the thrush as 'wise' because the bird 'sings each song twice over,' and thus shows his ability to 'recapture'

'The first, fine, careless rapture.'

It is also to be noticed that many birds can imitate other sounds, even those of the human voice. The repetition may be 'parrot-like,' but it gives evidence of the power of attending to a series of sounds.

It should be mentioned that the external ear of certain aquatic mammals is atrophied or lost. But as these animals have taken to a different kind of environment, and have been to so remarkable an extent made over, it seems unnecessary in the present investigation to give special consideration to this particular change in their structure.

The case of the monkeys seems at first to be different. Some of them, the anthropoid apes at least,* have like man lost the power to move the ears, yet they have not, it may be said, the faculty of speech. Have we not, then, the loss without any compensation of the special kind that is here being claimed for man? In considering this question we must keep in view the psychologist's ignorance of the mental life of the monkey. Notwithstanding all that has been written of the relationship of man to the monkeys, the psychology of these animals is still for the most part a blank. Yet there are some significant data that may in the present case be appealed to. The howling monkeys, though of low intelligence, find delight in the noise, from which they receive their name. They are gregarious and they howl in company. This noise is not made to drive away enemies; the monkeys gather deliberately for the purpose of making the noise and the leader starts the concert.

The chattering of monkeys should also be regarded as affording

* "The more recent ape ancestors, common to men and to the anthropoid apes (gorilla, chimpanzee, etc.) discontinued the habit of moving their ears and hence the motor muscles gradually became rudimentary and useless." Haeckel, 'Evolution of Man' (English Translation), Vol. II., pp. 270–271.

evidence of the appreciation which they have of sound. The chattering differs, moreover, from the mere monotonous repetition of a sound and if it has any function, it is probably a function which can be fulfilled only by the apprehension of a series of diverse sounds. It is also of interest to note the statement of Professor Haeckel that he has heard from apes of very different species 'remarkable clicking sounds'; and it has been thought that these sounds are still present in the language of Bushmen.

Mr. R. L. Garner made some years ago a study of the 'speech of monkeys,' and he reached the following conclusions:* "The sounds which monkeys make are voluntary, deliberate and articulate. They are always addressed to some certain individual with the evident purpose of having them understood. . . . They wait for and expect an answer, and if they do not receive one they frequently repeat the sounds. They usually look at the person addressed and do not utter these sounds when alone or as a mere pastime. . . . They understand the sounds made by monkeys of their own kind. . . . when imitated by a human being, by a whistle, a phonograph, or other mechanical devices. . . . The fundamental sounds appear to be pure vowels, but faint traces of consonants are found in many words." "As a rule each act of a monkey is attended by some sound." In a later work, Mr. Garner, after study of the apes in their native haunts, says that the chimpanzee has a vocabulary of twenty-five to thirty words; he claims that he learned ten of these words so that he could hold communication with the animals using them.†

Mr. Romanes'‡ account of the song, if such it may be called, of the chimpanzee 'Sally' may here be quoted: "It is sung without any regard to notation in a series of rapidly succeeding howls and screams —very loud, and accompanied by a drumming of the legs upon the ground." Mr. Garner has observed similar exhibitions given by chimpanzees. He also heard a performance of the kind in the African forest; the natives and others attributed it to the gorilla, but Mr. Garner thinks it not unlikely that it was given by the chimpanzee.

Darwin § calls attention to the fact that two species of the gibbon, the *Hylobates agilis* and the *Hylobates leuciscus* have musical powers. In regard to the song of the former he quotes Mr. Waterhouse, who says: "It appeared to me that in ascending and descending the scale, the intervals were always exactly half tones; and I am sure that the highest note was the exact octave to the lowest. The quality of the notes is very musical."

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* 'The Speech of Monkeys,' pp. 169–170.

† 'Apes and Monkeys,' p. 108.

‡ 'Mental Evolution in Man,' p. 377.

'Descent of Man,' p. 567.

In considering the linguistic development of monkeys it is important to remember that monkeys have to a striking degree developed social qualities. Detailed proof of this sociality need not be given; its existence is known from the accounts of travelers, and of those who have domesticated these animals, and, indeed, from observations in zoological gardens. The knowledge of it is very incomplete; yet enough is known to show that it is often very intimate and not without complexity. Where there is such a social life, it is to be expected that there will be found a development in the use of sounds. Not that the presence of this development is hereby proved, but a presumption is created in favor of the view that it exists.* Darwin† thought that primeval man probably first used his voice in the production of true musical cadences, especially during courtship; and that the imitation of musical cries by articulate sounds might have given rise to words expressive of various complex emotional states. Should we not rather find the greater development of vocal signs in the apes earlier than primeval man which had variety of vocal utterance combined with the varied emotions of a complex social life, emotions not only of courtship, as Darwin supposes, but of parentage and of the various relations of friendliness and hostility?

It is not meant that all the monkeys referred to have the immobile ear. This is characteristic of the anthropoid apes. It is important, however, to observe in very diverse species of monkeys the peculiar interest in sounds; and in the anthropoid apes, which have lost the mobility of the ear, there is, as we see from the accounts of the gibbon and the chimpanzee, the special development of the use of, and appreciation of, vocal and other sounds.

It seems at first sight that the gain in the use of vocal sound made by the apes is too slight to account for the change in the organ of hearing. Yet we must hesitate to pronounce such a verdict when we consider the immense importance of any improvement in the faculty of language. Let an analogous case be considered. Mr. Fiske has shown that the slow growth of the brain is a condition of the attainment of the preeminent mental faculties possessed by man. This prolongation of infancy is in itself a disadvantage, but the gain resulting from it more than counterbalances the loss. But we find a similar slow growth in the case of the apes. Can we find in them any notable gain in intelligence? While they are intelligent animals, we can not appeal to a distinct and unchallengeable superiority. Nevertheless, we believe on evolutionary principles that there is a gain in mental faculty to warrant the slow maturing of their powers. Even so in the

* Mr. Garner claims that 'the more pronounced the gregarious habits of any species' of monkey are, the higher 'the type of speech it has.'

† 'Descent of Man,' p. 87.

case of language, we must say that any new form in the organism which conduced to the evolution of this faculty would be of such moment that, unless it entailed seriously deleterious effects, its permanence would be ensured.

To sum up, the loss of the ear's mobility has resulted in the fuller appreciation of the succession of sounds, and thus has been in an important sense a condition of the social, intellectual and esthetic development which has come with the use of language and music; and it is in a high degree probable, though the data are insufficient for conclusive demonstration, that it is to the advantage given in the struggle for existence by the first stages of this development that we are to attribute the permanent alteration in the structure of the ear.

We thus see that the sense organ having originally the form best adapted to the conditions in which the organism lived changed its form to meet the conditions of a higher stage of evolution. It may be that in this form it is most in accord with the special stimulations which appeal to it; it is certainly in this form that it can minister to the highest spiritual activities.

SOME EIGHTEENTH CENTURY EVOLUTIONISTS.

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A SATISFACTORY history of the theory of descent is a chapter in the records of human opinion that is still to be written. Meanwhile the subject is one about which persistent errors and illusions of historical perspective prevail. The popular mind appears to be firmly possessed by the belief that the doctrine of the evolution of species was a scientific innovation first promulgated, or at all events first cogently defended, by Darwin; the fame of the natural-selection hypothesis has become so great that its author figures, in the eyes of the great public, as the parent of the whole transformist system, while the earlier half century of controversy in behalf of that doctrine, under the leadership of Lamarck and of Geoffroy St. Hilaire, is forgotten. How far even instructed persons may suffer from this illusion of perspective was illustrated in the recent commemorations of the Emerson centenary. More than one of the eulogists of the great moralist of New England descanted upon his very un-Darwinian lines which tell how—

> striving to be man, the worm
> Mounts through all the spires of form,

as a remarkable 'anticipation of Darwin' and an example of the power of the poetic imagination to divine scientific truth. But the lines in question, added to the editions of Emerson's 'Nature' after 1849, are, of course, merely an epigrammatic versification of the main doctrine of Robert Chambers's 'Vestiges of Creation,' published in 1844; and the conception they express could hardly have been a very original one at any time after the appearance of Lamarck's 'Philosophie Zoologique' in 1809. The same confusion is illustrated again in the persistency with which writers on Tennyson take it for granted that the famous passage in 'In Memoriam' about nature,

> so careful of the type,
> So careless of the single life,

is an echo of the 'Origin of Species,' which in reality did not appear until at least fifteen years after this part of the poem was written. Even Mr. Frederic Harrison has—as Mr. Lang has pointed out—fallen into this error; and Mr. G. K. Chesterton has recently written about Tennyson in a way calculated to give the error fresh currency. But

even those who do not forget that the theory of the transmutation of species has been a familiar and influential doctrine, established upon fairly conclusive arguments ever since the beginning of the nineteenth century, are likely to forget the fact that the doctrine, in its proper modern form, takes its origin, as a respectably fathered and militant hypothesis, in France in the middle of the eighteenth century. The histories of the theory of evolution* mention, indeed, a number of names in the eighteenth and in many earlier centuries, with which vague and more or less eccentric foreshadowings of the now accepted doctrine are connected. But the books on the subject which we have in English are unfortunately either inadequate or inaccurate or both; and they rather disguise than reveal the real character and significance of the evolutionist movement in the eighteenth century. Many of them—Mr. Clodd's book, for example, and Huxley's essay, and Professor Packard's 'Lamarck,' as well as the French works of Perrier and of Quatrefages on the precursors of Darwin—ignore some of the most important and most influential eighteenth century evolutionists; Professor Osborn's survey ('From the Greeks to Darwin,' 1894) is more comprehensive but regrettably inaccurate. There is therefore some occasion for a fresh attempt to clear up some points in the earlier history of the central conception of modern biology.

It is unfortunate that the eighteenth century manifestations of evolutionism should have so generally been grouped, by those who have written of them, in one class with the ancient adumbrations of Darwinism, as if all alike were merely interesting historic accidents. The ancient foreshadowings of the doctrine were, indeed, little more than happy but fortuitous guesses of ingenious minds. But the mid-eighteenth century outcropping of the theory was a natural, one may almost say an inevitable, consequence of the progress which had up to that time been made in natural science. And the theory found expression, not in the sporadic utterances of an obscure philosopher here and there, but in the best-known writings of three of the most celebrated leaders of the opinion of their time; so that, however little it may have gained acceptance, the theory must have been pretty widely known among their contemporaries. It is, of course, a fact sufficiently familiar that Buffon in 1749 propounded the conception of the transformation of species as a possible hypothesis; that he pointed out the homological evidence in favor of such an hypothesis, and tended in some passages to accept it; but that, in his most important passage on

* In this paper the word 'evolution' is used in its common contemporary sense, as meaning the descent of species from earlier species. The reader will, however, remember that in the eighteenth century the same term was employed to designate the process of the generation of individual organisms as conceived by the preformationist,—*i. e.*, the process of the literal 'development' or unfolding of the ready-made and preexisting parts of the embryo. Most 'evolutionists' in this eighteenth century sense were not evolutionists in the more modern sense in which the word is here used.

the subject, he rejected it, partly on grounds of religious orthodoxy. Professor Packard, in his life of Lamarck, has recently presented an interesting study of Buffon's exact position in the matter. These equivocal expressions of Buffon's are, however, commonly spoken of as if they were unique in their period; whereas the same hypothesis was put forward, within a decade, by two countrymen of his who were hardly less representative than he of the scientific progress of their generation. For one of them was the president of the Royal Academy of Science of Berlin; and the other was the editor of the Encyclopædia.

There were two distinct lines of development in scientific investigation and theory during the first half of the eighteenth century which led up to and suggested the theory of transformation as a natural and probable hypothesis in zoology. The first of these was the active prosecution of both observation and speculation in the field of embryology; the second was the development of the new science of comparative anatomy at the hands of Daubenton. The representative of the former way of approach to evolutionism is Maupertuis. In speaking of him, I venture to improve the occasion to give some general account of his place in the history of science, since the matter is one about which little trustworthy information appears to be generally accessible. Such an account will make the significance and the grounds of his evolutionary opinions more apparent.

I. *Maupertuis.*—Although not without some reputation as the reorganizer of the Berlin Academy*—for which task he was especially imported from France by Frederick the Great—and as the director of the first expedition to demonstrate the flattening of the globe at the poles by the measurement of a degree of longitude at different latitudes, Maupertuis is usually made to play a somewhat comic rôle in the literary history of his century, as the rival of Voltaire for the favor of Frederick and as the victim of one of Voltaire's most ferocious satires. Although Frederick took the side of Maupertuis in that famous quarrel and caused the copies of Voltaire's libel to be burned by the hangman in all the public places of Berlin, the satirist has been more successful in gaining the ear of posterity. Immensely famous and respected as a sort of scientific oracle in his own day, Maupertuis seems now to be best known through the misrepresentations of his adversary; there is even reason to fear, from internal evidence, that some learned historians of philosophy, in the little they have to say about the 'Native of St. Malo'—as Voltaire always designated him—have depended more upon the 'Histoire du Docteur Akakia' than upon a careful examination of Maupertuis's own writings. Yet—in spite of the touch of vanity which sometimes made him ridiculous and the superficiality of a good deal of his knowledge—his reputation deserves in some measure

* For the earlier history of the Berlin Academy, see *The Popular Science Monthly*, March, 1904.

to be rehabilitated. He was by no means a great scientific investigator; his work in physics and in astronomy, which he professed for his chief specialties, seems to be of decidedly questionable accuracy and value. His celebrated 'law of least action,' which was the original occasion of his quarrel with Koenig and Voltaire, was a generalization vaguely conceived and ill formulated, although, as Mach has pointed out, it was taken up by Euler, the friend and partisan of Maupertuis, and transformed into an important physical principle. But in any history of the general movement of scientific thought in his century Maupertuis clearly merits a place of some distinction. For he was the possessor of a wide view of the interrelation of different scientific problems; he was an ingenious and yet often a pretty shrewd and critical interpreter of the bearing and ulterior consequences of the scientific discoveries of others; and he contributed to more than one branch of science new and important conceptions, which during the subsequent century and a half have come into great vogue and in some cases into general acceptance.

As was the fashion of his time, Maupertuis took philosophy as well as physical science for his province; and before considering his work in the latter domain, it is worth noting that in the former also he was the proposer of several notions, now familiar enough, which were at the time relatively novel and contrary to the prevailing intellectual fashions. As a moralist, for example, Maupertuis raised a question that has been repeated with much doleful iteration by his nineteenth century successors, but one highly paradoxical to his contemporaries: In ordinary human life, does the sum of dissatisfactions exceed the sum of pleasures?* This question he answered in a pessimistic sense, in an age when a superficial optimism was the proper note among enlightened *philosophes*—and was reproached for it by the writer who, a few years later, was to produce the 'Poem on the Lisbon Disaster' and 'Candide.' In laying down the logical conditions for dealing with such a question, Maupertuis anticipated Bentham and the 'moral arithmetic' of the Utilitarians, by elaborating a species of hedonic calculus, in which careful definitions are offered, not only of the nature of pleasure and pain, but also of the several dimensions of each that must be reckoned in assessing the relative value of any two 'sums of pleasure,' or of its contrary. As a political theorist, also, he shows himself a precursor of the English Utilitarian school, at a time when nearly all the new systems of political philosophy were based upon some form of the conception of 'natural rights' or 'natural law.' In his 'Eloge de M. de Montesquieu' he criticizes the political doctrine of the 'Esprit des Lois,' which rests, he says, upon the assumption that there inheres in human relations 'un certain rapport d'équité' which man's reason immediately recognizes. "It is not," writes Maupertuis,

* 'Essai de philosophie morale,' chaps. 1 and 2.

"such a principle as this that should be accepted as the fundamental principle of legislation; this is too obscure, too vague, too susceptible of different interpretations; it would leave too much to the arbitrary judgment of the legislation." The only safe guide in legislation is the *principe du plus grand bonheur*. "The problem of the legislator is simply this: A multitude of men being collected together, to procure for them the greatest sum of happiness possible. It is upon his principle that all systems of legislation should be based." All this reads like so many sentences from Bentham himself; and the resemblance is by no means merely coincidental. In the ethical and political writings of Maupertuis and of Helvétius we have the head-waters of the important stream of utilitarian influence which became so broad and sweeping a current through the work of the Benthamites. Bentham read Maupertuis early—perhaps about 1770, in his twenty-second or twenty-third year, thinks a recent writer on the subject*—and although he had already got the suggestion of his doctrine from Priestley and Helvétius and Beccaria, he found, as he himself tells us, his utilitarian tendencies strengthened and corroborated by his reading of the 'Essai de Philosophie Morale.'† The utilitarian political teaching of Maupertuis was enunciated at least three years before the publication of a similar doctrine in the book of Helvétius (*De l'Esprit*, 1758); and that book, Mr. John Morley has said, 'contained the one principle capable of supplying such a system of thinking about society as would have taught the French of that time in what direction to look for reforms.' The work of Beccaria, the third of the early influences upon the mind of Bentham, was still later in date of publication (1764).

In treating of the relation of scientific method to theology, Maupertuis—although professing a somewhat perfunctory religious orthodoxy—criticized the favorite eighteenth century argument for theism—the so-called argument from design—in which the deists no less than the orthodox of the period found the principal basis of their religious philosophy; and his criticism upon it is just such as a Darwinian might now make. It closely resembles, indeed, the criticism of the same argument that Romanes put forward long afterward as a special outcome of Darwinism.‡ Many, says Maupertuis, have found an evidence of design in the marvelous adaptation of the organs of animals to their needs. But "may we not say that, in the fortuitous combination of the productions of Nature, since only those creatures *could* survive in whose organization a certain degree of adaptation was present (*ou se trouvaient certains rapports de convenance*), there is nothing extraordinary in the fact that such adaptation is actually

* Halévy, 'La jeunesse de Bentham,' 1901, p. 288.

† *Ibid.*, p. 406.

‡ 'A Candid Examination of Theism.'

found in all those species which now exist? Chance, one might say, turned out a vast number of individuals; a small proportion of these were organized in such a manner that the animals' organs could satisfy their needs. A much greater number showed neither adaptation nor order; these last have all perished. . . . Thus the species which we see to-day are but a small part of all those that a blind destiny has produced." Maupertuis did not dogmatically maintain the anti-teleological position which this criticism tended to justify; he only maintained that zoology can not assist theology, because the former has no need of teleological explanations and can sufficiently account for the degree of adaptation which exists on the principle which we should now call that of the survival of the fittest, *i. e.*, of the best adapted.

Maupertuis had also his own theories in metaphysics; but these are so closely connected with his evolutionary views that the two should be considered together. I turn, then, to mention his work in promoting new ideas in natural science. He was the first to introduce the Newtonian physics and astronomy into France. In the face of a good deal of opposition, he successfully disseminated the doctrine of attraction among the learned; and it was apparently from him that Voltaire acquired a sufficient smattering of physics and astronomy to enable him to write his 'Eléments de la Philosophie de Newton' (1738). As became the president of an academy, Maupertuis undertook, in his 'Lettres' and 'Lettres sur le Progres des Sciences'* to sum up certain of the most important gains that had been made by scientific inquiry, and to lay down a program of experimental investigations next to be undertaken. These investigations, he urged, should be supported by the state, when they are too elaborate or too expensive to be undertaken by private enterprise. Some of his suggestions are pretty fantastic and impracticable; but the greater number show good sense and a keen appreciation of the importance of systematic experimentation, even in sciences where experimental methods had as yet been little used. He recommends, among other things, the exploration of the north and south polar regions, and of the interior of Africa, for the settlement of the chief unsettled questions in geography; urges the employment of experimental methods in zoology, especially in the study of the problems of heredity; advises specialization in medical

* 'Oeuvres,' 1756, tome II. The proposals contained in these letters were the special objects of Voltaire's ridicule. But—M. Desnoiresterres ('Voltaire et Frédéric,' ch. 8) to the contrary notwithstanding—Voltaire gains nearly all his effects either by deliberately misrepresenting Maupertuis, or by presenting as absurdities ideas which to the unprejudiced will rather seem evidences of soundness of judgment. The Kantian idealist of our time, for example, will find some lack of point in this attempt at the ironical: 'Le candidat (Maupertuis) se trompe, quand il dit que l'étendue n'est qu'une perception de notre âme. S'il fait jamais de bonnes études, il verra que l'étendue n'est pas comme le son et les couleurs, qui n'existent que dans nos sensations, comme le sait tout écolier.'

practise; proposes the utilization of the bodies of condemned criminals for experiments on the etiology of disease; calls for the prosecution of systematic experiments with electricity, and the abandonment of premature efforts to make practical use of that force, before its properties and behavior had been adequately investigated; and indicates the possibility of the prosecution of certain *expériences métaphysiques*—*i. e.*, of investigations in what we should now call experimental psychology. He concludes his program somewhat humorously with an enumeration of *récherches à interdire*—namely, those 'chimeras of science,' the philosopher's stone, the quadrature of the circle and perpetual motion. In regard to the first of these, however—the transmutation of elements—he points out that the thing can not be shown to be inherently impossible. For there are several legitimate hypotheses about the constitution of matter which are compatible with the possibility of transmutation. It is not unlikely, for example, that 'matter is composed of homogeneous parts,' and that the elements which appear to possess irreducible qualitative differences, 'really differ from one another only by the dissimilar form and arrangement of the homogeneous particles which compose them.' In that case, we should not be entitled to declare it impossible to give 'to such particles a different form and arrangement, which is all that would be necessary in order to transmute lead or wool into gold.' The objection to the search for the means of transmuting elements is, therefore, not that it can be demonstrated to aim at the impossible, but only that in the existing state of science, the value of the goal—great as it would be—'is not great enough to counterbalance the scant probability of attaining it.' When one reminds oneself of the hypotheses about the constitution of matter that have come into especial vogue since the discovery of the properties of radium, these observations strike one as the expression of a rather well balanced judgment.

It was, however, in his conception of the methods and the possibilities of natural history that Maupertuis most evidently showed himself the possessor of a wider intellectual horizon than was common among the men of science of his time. Zoologists had as yet seen little occasion to attempt more than the careful description and classification of animals; but to Maupertuis a purely descriptive and classificatory science, which was unable to formulate any laws concerning the *processes* going on in that part of nature with which it dealt, was, strictly speaking, no science at all. He had little patience with naturalists whose view of their province was so narrow. 'All these treatises on animals which we as yet have,' he writes in the 'Lettres sur le Progrès des Sciences,' 'are —even the most methodical of them—no better than pictures pretty to look at; in order to make of natural history a veritable science, naturalists must apply themselves to researches which can make us acquainted, not simply with the form of this or that animal, but with the general

processes of nature in the production of animals and the conservation of them.' The general processes which Maupertuis thought it especially important that zoological science should investigate are those through which animal individuals and species have come to have the differences of form and function that distinguish them. Maupertuis, in a word, appears to have clearly envisaged the genetic problem in biology, at a period in the history of thought when genetic problems generally were little considered. The center of interest in zoology therefore lay, for him, in the problems of embryogeny and of heredity. Although not himself an anatomist, he made himself familiar with investigations made by others on the minute anatomy of the embryo. And, as I have intimated, he never tired of insisting that the facts of heredity should be investigated, in the case of animals, by experiments in the interbreeding of species and varieties, and, in the case of human beings, by a collation of family histories.

The opinions of Maupertuis on these matters are expressed chiefly in the work called 'Vénus Physique' (1745) and in the 'Système de la Nature' (1751). The latter first appeared in the form of a Latin dissertation ostensibly delivered at Erlangen by one Dr. Baumann. Maupertuis found it expedient thus to shelter himself against reproach on account of any heterodox tendencies that the book might be found to contain. Four editions—all but the first in French—were called for within four years, and the author soon assumed responsibility for his work. In the 'Vénus Physique' Maupertuis essayed the popular style, and the book is consequently marred by passages written in an abominably rhetorical and affected manner. But, none the less, it constitutes, if I am not mistaken, the first important attack made in the eighteenth century upon the theory of the preformation of the embryo. Harvey had advanced the doctrine of epigenesis nearly a century earlier, but his arguments had failed to convince his successors, and his observations upon the chick had been shown by Malpighi to be partially erroneous.* At the time when Maupertuis wrote, preformationism had long been the ruling doctrine in embryology; an immense weight of scientific authority was in its favor. Among the philosophers Malebranche and Leibniz had argued for it, among the great physiologists and anatomists Swammerdam, Redi, Malpighi, Leeuwenhoek, Winslow and Haller had taught it. Bonnet was yet to give it its most elaborate exposition and defense; and three quarters of a century later it was still to find an adherent in Cuvier. The 'Vénus Physique' is a review of the preformation theory in its several forms, designed to show that the evidence against it is conclusive.

Of the arguments for epigenesis which Maupertuis offers it is not possible, in this brief paper, to give any sufficient account. He relies in part upon the observations of Harvey—and in so doing shows himself

* 'De formatione pulli in ovo,' 1673; 'De ovo incubato,' 1686.

not quite abreast of the anatomical knowledge of his time, since, correct as Harvey's main conclusions were, the observations upon which he based them had already been superseded. Chiefly, however, Maupertuis rests his case upon the facts of double heredity and hybridism. If the embryo be truly 'predelineated' in the ovum or in the 'zoosperm,' how, he asks, can it come about that it inherits the specific or individual characters of now one and now the other parent, and often of both? The preformationists had, of course, their devices for explaining away this pretty obvious difficulty; but Maupertuis finds it easy to show that the explanations are altogether inadequate when they are compared with even the common and easily observable facts of heredity. His reasoning is especially effective when he cites his own investigation of the transmission of hexadactylism (*sexdigitisme*) through several generations of a certain German family whose records he had examined, and points out how little the preformation hypothesis could account for the transmission of such a peculiarity through male and female parents alike, its progressive disappearance as succeeding generations more and more intermarried with persons having the normal number of digits, and its occasional atavistic reappearance in remote descendants. In view of these classes of facts, he declares, the encasement theory must be abandoned, and the conclusion must be accepted that the embryo is no ready-made article, preexistent from the creation of the world, but a new birth, the product of a true genesis;—not, indeed, a genesis of life itself, but of a new and unique combination and intermingling of already-living elements contributed by both parents alike. These arguments and this conclusion, it should be remembered, were advanced by Maupertuis more than a decade before the publication of the great work of Kaspar Friedrich Wolff,* from which the modern revival of the doctrine of epigenesis is usually dated. The conception of epigenesis held by Maupertuis, was, moreover, far more complete and accurate than that which Harvey had put forward a century earlier. For although Harvey had asserted *marem et foeminam pariter efficientes causas esse generationis,* he had denied that there can be any physical interpenetration of ovum and spermatozoon, and had declared that fecundation consists in the communication of a purely immaterial force. It was in order to make this a little more intelligible that Harvey had worked out his famous analogy between the conception of the embryo in the uterus, and the conception of an idea in the brain.† All this, Maupertuis remarks, is an *idée étrange;* where we have double

* 'Theoria Generationis,' 1759.

† Harvey's reason for this opinion lay in his failure to discover any traces of the spermatozoon in the uterus. His own words are 'Quoniam nihil sensibile in utero post coitum reperitur; et tamen necesse est ut aliquid adsit, quod foeminam foecundam reddat; atque illud, ut probabile est, corporeum esse nequeat: superest ut ad merum conceptum, speciernmque sine materia receptionem, confugiamus,' *i. e.*, the ovum is fertilized by being impregnated with a general concept! ('De generatione animalium,' 33).

heredity we must assume a communication of corporeal elements, vehicles of that heredity, from both sides. And, as Maupertuis also observed, the supposed fact by which Harvey had justified this singular conclusion had already been rendered more than questionable by later investigations of Verheyen.

Having established these essential principles to his satisfaction, Maupertuis proceeded to formulate an hypothesis concerning the nature of the fundamental physical process presupposed by the facts of heredity, on the one hand, and of variation, on the other. The formation of an embryo must, he conceived, be due to the combination in a new organic union, of a great number of living corporeal particles, derived usually from both parents, each of which particles carries with it a sort of organic memory (*souvenir*) of the life of the organism to which it formerly belonged, and thereby tends to unite with the other particles in such a way as to produce a new organism of the same species.* This process of recombination of already living particles was held by Maupertuis to be governed by something more than the laws of mechanism; embryogeny was for him no mere process of juxtaposition, under the laws of gravitation, of so many inert atoms; the ultimate units of the newly constituted living being all possess their own self-contained law of development, and their own distinctive selective affinities for certain other units. None the less, purely mechanical displacements of parts also take place; and to these in part, he supposed, is due the occurrence of monstrous forms, and many of the more ordinary variations from the hereditary specific type. Moreover, the elementary units which, coming from the parents, combine to form the embryonic offspring, in part carry with them a similar sort of organic memory of the particular and individual characters of the parent, and so tend to develop those characters in that offspring; but in part also they are free from this tendency, and carry with them rather the traits of more remote ancestors (atavism), and some of them may even be wholly independent of hereditary predetermination. It is these especially which, in Maupertuis's hypothesis,† constitute the explanation of the general tendency to variation in animals, which he recognized to the full. If one must have a further explanation why the transmitted corpuscles tend to reproduce the characters of the parents, Maupertuis suggests that perhaps there enters into the embryo a separate germ from each part of the body of the parent of which the character is reproduced; in other words, he proposes a hypothesis similar to the Dar-

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* 'Vénus Physique,' Pt. II., ch. 5. We must suppose 'que la liqueur séminale de chaques espèce d'animau, contient une multitude innombrable de parties propres à former par leurs assemblages des animaux de la même espèce.

† *Loc. cit.* It is likewise to be assumed 'que dans la liqueur séminale de chaque individu, les parties propres à former des traits semblables à ceux de cet individu sont celles qui d'ordinaire sont en plus grand nombre, et qui ont le plus d'affinité; quoiqu'il y en ait beaucoup d'autres pour des traits différents.'

winian theory of Pangenesis. All these ideas are put forward by Maupertuis only as so many likely explanations of facts which, as he insisted, needed more adequate analysis and explanation than the embryological doctrines of the time afforded; his pangenetic theory, in particular, he regarded only as *une conjecture bien hardie, mais qui ne serait peut-être pas destituée de toute vraisemblance.*

What is noteworthy in these hypotheses is the group of truths which they involve incidentally. From Maupertuis's exposition of them it is clear that he had been led, by his reflections upon the facts of heredity, to recognize (*a*) that there is a constant tendency to variation in animals by reason of their double heredity; (*b*) that there is a further tendency to spontaneous and accidental variations, due in part to mechanical displacements or chance combinations among the ultimate particles of which the embryo is composed; (*c*) that these variations —and possibly also new characters acquired during the lifetime of the parent*—tend to be perpetuated through heredity, provided that they do not unfit the animals that possess them for survival in their environment, and provided also that they are not gradually obliterated through inter-breeding with animals that do not possess them. To one who thus emphasized the factors making for variation and for the conservation of variations, the theory of the mutability of species necessarily appeared more natural than the theory of their fixity. Maupertuis thus passes at once from his theories of heredity to propound the hypothesis that all species may have come from a single primitive pair through the gradual accumulation and transmission of divergent variations. Granting these facts about variation, he writes, "would it not be possible to explain by means of them how the multiplication of the most dissimilar species might be traced back to (*aurait pu s'ensuivre de*) only two individuals. Such species would have owed their origination merely to the accidental production of certain embryos (*à quelques productions fortuites*) in which the elementary parts had not retained the arrangement which they had had in the parent animals. Each degree of deviation (*erreur*) would bring about a new species; and by means of repeated departures from the original form (*à force d'écarts repétés*) there would have come about the infinite diversity of animals that we see to-day:—a diversity which may in time increase still further, but to which it may be that the lapse of centuries will bring only imperceptible additions" ('Système de la Nature,' XLV.). In the 'Lettres' Maupertuis again writes, *à propos* of the inheritance of certain congenital individual variations in the human

* Maupertuis raises the question concerning the inheritance of acquired characters, but suspends judgment upon it, and calls for further experimentation. 'Ce serait assurément quelque chose qui mériterait bien l'attention des philosophes, que d'éprouver si certaines singularités artificielles des animaux ne passeraient pas, après plusieurs générations, aux animaux qui naîtraient de ceux-là.'

species: "I hold that these supernumerary digits are, at their first appearance, nothing but accidental variations. . . . But these variations once well established (*confirmées*) through a sufficient number of generations in which both sexes have had them, constitute (*fondent*) species; and it is perhaps thus that all species have multiplied." In fact, for Maupertuis the difficulty lay in explaining, not how species are transformed, but why they are so stable.

It will be seen that Maupertuis puts forward his theory of transformation only as a likely hypothesis, not as a settled truth. But it is an hypothesis for which he clearly enough indicates his own preference; and it is certain, from a passage of Diderot's which I shall presently quote, that his contemporaries looked upon him as the typical representative of the doctrine of the descent of all species from a primitive type. Yet the significance and originality of the work of Maupertuis lie not so much in his explicit enunciation of the theory of descent, as in the fact that he (1) insistently called the attention of naturalists to the problems connected with the genesis and transmission of variations; (2) framed a conception of the processes involved in embryogeny and heredity which made the mutability of species seem antecedently the more natural and more probable hypothesis; (3) indicated a program for systematic observation and experimentation with reference to heredity and to the effects of interbreeding, which, if carried out, would have transformed zoology; (4) intimated that Nature produces a far greater number of types and of individuals than she can maintain, and that among all these variant types there is constantly taking place a process of natural selection whereby those unfitted to the conditions of their life are exterminated; (5) explained the adaptation of animals to their environment solely as the result of these conjoint processes of variation and selection.*

* Professor Osborn, unlike most of the historians of evolutionism, makes some mention of Maupertuis, but classifies and describes his doctrines in a very curious fashion. He classes the president of the Berlin Academy, as well as the editor of the Encyclopædia, with such 'evolutionists' as de Maillet (who 'derived man from *l'homme marin*, the husband of the mermaid'), and Duret (who asserted that there were trees in Scotland, the leaves of which, falling on one side into the sea, became fishes, and falling on the other side on land, became birds). Of all these equally Professor Osborn says: "They were not actually in the main evolution movement; they were either out of date or upon the side-tracks of thought. They can be sharply distinguished from both the naturalists and the philosophers in the fact that their speculations advanced without the support of observation, and without the least deference to inductive canons." Such a characterization, applied to men like Maupertuis and Diderot, certainly fails somewhat in deference to the ordinary canons of historical accuracy. Professor Osborn mentions, indeed, that 'an obscure article' (the 'Système de la Nature) by Maupertuis 'has been unearthed in the course of the present diligent search for all the prophecies of evolution,' and a partially correct account is given of some of the contentions of that writing. But no clear indication is given of the grounds of the evolutionism of Maupertuis; and the writer of 'From the Greeks to Darwin' appears to have been unacquainted with the 'Vénus Physique' and to have ignored the work of Maupertuis in the rehabilitation of the doctrine of epigenesis. He implies also that Buffon's theory

It remains to point out that the embryological doctrines of Maupertuis were intimately connected with certain metaphysical conceptions, of a type that has often since shown itself to be peculiarly congenial to minds trained in biology. The 'Système de la Nature' is primarily an exposition and a defense of the theory that all matter possesses some sort of consciousness—a 'monism' similar to that of which Haeckel is the contemporary prophet. A purely mechanistic materialism, such as the atomism of the Epicureans, or the crude notions which La Mettrie had recently put forward, seemed to Maupertuis an evident absurdity; 'in order to overthrow such a system,' he writes, 'one need do no more than ask those who hold it how it would be possible for atoms without intelligence to produce an intelligence.' Mere mechanism appeared as little capable of explaining the phenomena of organic life, as it was of explaining the phenomena of consciousness; especially manifest, Maupertuis thought, is the inadequacy of purely mechanical causes to account for the processes which he conceived to be involved in the formation of the embryo. "A blind attraction uniformly distributed throughout all particles of matter can not serve to explain how these particles arrange themselves to form even the simplest of organized bodies. If they all have the same tendency, the same power, to unite with one another, why is it that certain elements go to form the eye, certain others to form the ear, etc.? Why this marvelous arrangement? Why is it that the various elements are not united pell-mell?" The combination of material particles to form a living organism seemed to imply a principle of selection, a species of elective affinity between the particles, which could not be reduced to physical or chemical categories; and the singular fact of heredity, the transmission of qualitative similarities from one organism to another through whatever minute bodies serve as the vehicles of heredity, seemed to imply the possession by those bodies of something which could only be conceived under the analogy of conscious memory. It is necessary, then, to attribute to each particle of matter the possession of some rudimentary forms of sentiency, memory and volition. (*Si l'on veut dire sur cela quelque chose qu'on conçoive, quoiqu'encore on ne le conçoive que sur quelque analogie, il faut avoir recours a quelque principe d'intelligence, a quelque chose de semblable a ce que nous appellons désir, aversion, mémoire*). Maupertuis does not forget the radical difficulty which has been urged against the identification of the *res cogitans* and the *res extensa* ever since Descartes—the difficulty, namely, that the attributes of consciousness and extension have nothing in common, and that neither can thought be conceived as ex-

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of generation appeared earlier than that of Maupertuis, which is not the case. The general conception of the 'evolution movement' and of the relative importance of its several eighteenth century representatives, in Professor Osborn's book, seems to the present writer decidedly misleading.

tended, nor extended matter as possessing the unity characteristic of conscious thought. Maupertuis certainly can not be said to meet this difficulty; but he evades it by a device which has been much employed since his time by metaphysicians of opinions kindred to his. The objection in question, he avows, would be a legitimate one against any doctrine that actually asserted the identity of matter and consciousness, reducing matter to thought, or thought to a form or function of matter. But if we say that thought and extension are not things, but properties—distinct but joint properties of a common subject—the difficulty, he contends, disappears. This *tertium quid,* of which thought and extension are to be defined as coexisting properties, is something 'of which the essence is unknown to us' ('Syst. de la Nat.,' 22). Maupertuis at this point appears, on the one hand, as repeating the dialectical strategy of Spinoza, a philosopher almost wholly ignored in the eighteenth century; and, on the other hand, as a precursor of Mr. Herbert Spencer, with his conception of the 'double aspect of an ultimately unknowable substance.' Maupertuis, however, was not a psychophysical parallelist; on the contrary, as I have pointed out, the sentiency which he attributed to matter was regarded by him as an essential factor in the explanation of physical events.

How Maupertuis would have reconciled the apparent—even though 'transfigured'—realism of this doctrine of conscious matter with the idealistic view of the subjectivity of the perception of space, which he expresses in one of the Lettres,* it is impossible to say. It may be that it never occurred to him that the two opinions were discrepant; it may be that he conceived it possible to reconcile them; and it may be that the idealistic view, which was published later than the other, implied the abandonment of the realism of the mind-stuff theory. As it is, we can only say that, as a metaphysician, Maupertuis has the apparently contradictory distinction of having given utterance, during the middle decade of the eighteenth century, to the favorite contentions of both the realism and the idealism of the nineteenth.†

* Lettre IV. 'Sur la manière dont nous apercevons.' For Voltaire's comment on this, see above, p. 9, footnote. Maupertuis expresses this idealistic conclusion in these terms: 'Refléchissant donc sur ce qu'il n'y a aucun rapport, entre nos perceptions et les objets extérieurs, on conviendra que tous ces objets ne sont que de simples phenoménes: l'étendue, que nous avons prise pour la base de tous ces objets, pour ce qu'en concerne l'essence, l'étendue elle-même ne sera rien de plus qu'un phenoméne.'

† Historians of philosophy have unduly neglected both aspects of Maupertuis as a metaphysician. Lange merely mentions his doctrine of 'empfindende Atome' in a sentence ('Gesch. d. Materialismus,' I., 259); Erdmann, who devotes a page to Maupertuis, says nothing about his metaphysics at all ('History of Philosophy,' II., 293, 4).

(*To be continued.*)

SALT.

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EVERYBODY knows the lines in Lucile in which the author declares that 'civilized man can not live without cooks.' He also proposes the query whether there is any man in the world who can live without dining. The assertion is true only with important restrictions; for it will not be contended by anybody that every person who cooks is a cook, any more than it would be affirmed that every one who paints is a painter. The interrogatory may be frankly answered in the negative, since the great majority of mankind does not now dine and never has dined. They eat when they have food, and when they have none they do without. If we call this spasmodic way of supplying the interior department with materials for slow combustion, quadrupeds may be said to dine with as much propriety as *homo erectus*. If our poet had asked the question, Where is the man, civilized or uncivilized, who can live without salt? every one of his readers would probably have replied unhesitatingly, 'He does not exist.' It is doubtful too whether he ever existed. It is asserted by competent authorities that terrestrial as well as marine life is conditioned upon the consumption of salt. The position is hard to prove or disprove, as experiments that would give trustworthy results are almost impossible. It seems, however, fairly well established that man at the present day, no matter what his rank on the staircase of social progress, can not or, at least, does not, live without this substance. What history has to say will be given below. That a historical record and an established fact are not interchangeable terms is, however, to be premised. Not only has this mineral been found in close proximity to almost every locality inhabited by man or at least within his reach; it is sought with almost equal avidity by brutes. Most domestic animals are particularly fond of it. It is said to be fatal to some kinds of birds, though barn-yard fowls consume it without injury. The herbivora have an especial liking for it, whether in their wild state or domesticated. It is well known that the various salt licks in the United States were favorite places for ambuscades, and that both Indians and whites used them for the purpose of destroying the deer, buffalo and other animals that habitually resorted to them. Probably the most famous of these salt springs, or licks, as they are generally designated, is the Big Bone Lick

in Boone County, Kentucky. Professor Shaler in his history of the state says:

> Not only do we find the bones of animals which occupied the country when the whites first came to it—the buffalo, the elk, the deer, etc.—but also deeper in the mire, or in portions that indicate a greater antiquity, great quantities of the bones of the fossil elephant, his lesser kinsman the mastodon, the musk-ox, an extinct long-legged buffalo, the caribou or American reindeer, and various other creatures which dwelt here in the time when the last glacial period covered the more northern regions with a mantle of ice.

The number of animals buried in the swampy soil about this lick is enormous. Many of them, in their eagerness to get at the brine, rushed beyond their depth, and before they were aware of it were borne down by their own weight until they were unable to extricate themselves, and so died of starvation. Others were probably pushed forward by those that crowded on from behind and trodden into the soft earth, where they died of suffocation. The locality was equally fatal to small and to large animals. How many years or cycles ago this destruction began we have no means of knowing, but that it continued to comparatively recent times is extremely probable.

Let us now examine some evidence which goes to show that man has lived without salt. Sallust in his 'History of the Jugurthine War' says the Numidians live chiefly on milk and the flesh of wild animals, and that they use no salt or other relishes. Not only is the time to which the historian refers comparatively recent, but he has the reputation of carefully verifying his facts. His statements, therefore, carry great weight. It is held, moreover, that the Finnish name for salt is derived from an Indo-European root. If this view is correct the inference is natural and legitimate that the Finns did not know this commodity until they came in contact with Aryans, probably Slavs, from whom they got both the name and the thing, or rather the thing and the name by which they heard it called. In the Odyssey the renowned seer, Teiresias, directs Ulysses to travel until he comes to 'men who know not the sea neither eat meat flavored with salt.' Pliny supposes the Epirotes to be meant by this passage. But the point of chief interest is that to the Homeric Greeks a saltless people were supposed to live somewhere in the interior and in the most primitive condition. The poet, instead of naming a dozen points of difference, with epic prolixity, in life and usage between his own nation and this far-off tribe, has selected a single characteristic as sufficiently explicit for his purpose. Tacitus relates that toward the close of the first christian century a great battle was fought between the Hermanduri and the Chatti for the possession of a river boundary, a salt-producing stream, because both parties believed that at this place heaven was especially near and that nowhere else could they address their prayers to the gods

in such close proximity. There is reason to believe that this river was the Werra. On its banks, near the town of Salzungen, saline springs have been known from time immemorial and are still in use. The historian further relates that salt was produced near the river and in the contiguous forest, not, as elsewhere, by the evaporation of sea-water, but by pouring brine over a pile of burning wood, with the result that the salt was precipitated as a consequence of the struggle between the two elements, fire and water. Evidently the sacred character that was supposed to attach to this saline substance was due to the belief held by the natives that salt was always a product of the sea, except by the special interposition of the gods, as in this case. That they had contracted a liking for salt elsewhere in their wanderings may be taken for granted.

Salt is now produced in many parts of Germany, but its existence in any form was not known at this remote period. The article produced in such a singular manner must have been very impure; but the palates of the primitive Germans were much less sensitive than those of their modern successors. At a later period the Alemani and the Burgundians are said to have frequently striven in battle for salt pits or saline springs claimed by both; but the region can not be definitely located. The record is chiefly interesting when taken in connection with the preceding and others of a similar character as showing the high value placed upon this substance by peoples that had hardly made a start along the highway of civilization. With respect to the above-mentioned method of making an impure grade of salt, it is worth noting that it is also spoken of as employed elsewhere. Varro had heard of a region where the inhabitants knew no salt, but used instead as seasoning a kind of salt coals which they obtained from burning wood. The same method and the same substitute for real salt are also reported as employed by some of the natives of Spain. Pliny devotes a good deal of space in his 'Natural History,' that storehouse of information and imagination, to the consideration of salt. He enumerates somewhat in detail the different places in almost the entire known world where it is found, describes the various methods of its production, notes the fondness of cattle for it, and adds that when mixed with their food it increases the quantity and improves the quality of the cheese. According to him Ancus Martius, the fourth king of Rome, established the first salt works, and the Romans perform no sacred rites without *mola salsa*. By the Romans salt was regarded as almost the staff of life, and the salt-cellar was preserved in families because it was supposed to have a quasi-sacred character. In one of his Odes, Horace tells his friend, Grosphus, that the man who enjoys life is he whose father's salt-cellar gleams on his table. In a satire by the same poet, the rustic sage informs the epicure that bread with salt will

appease his growling stomach, and advises him to spurn dainty viands. The cognomen Salinator, borne by a member of the Livian gens, came into prominence for two reasons. The first who received the appellation is said to have imposed a new impost on salt. He is further distinguished for the magnanimity he displayed in laying aside his private grudge against the other consul, Claudius Nero, for the good of the commonwealth. The hearty cooperation of the two commanders-in-chief and their armies led to the death of Hasdrubal and the complete destruction of his army. Wherever a system of taxation is framed with a view to raising the largest possible revenue, the heaviest burden falls on the necessaries of life. From almost time immemorial salt has had to bear a disproportionate share of this load. It is probable that in ancient times all regularly organized governments derived some revenue from this commodity. In Italy, as we have seen, the beginning was made long ago, though the details are lacking. In that country it is still a government monopoly. The profits realized are about thirteen hundred per cent., and its cost is almost prohibitive to the very poor. Such a delicacy do their children consider it that if they are allowed to choose between sweetmeats and salt they take the latter in preference. That a more liberal use of salt would improve the health and sanitary condition of this class hardly admits of a doubt.

It is safe to say that no article of consumption has been so ruthlessly exploited by governments to the detriment of their subjects as this one. Taking advantage of the fact that it is a necessary concomitant of the food of man and beast, they have made it an important source of revenue because its payment could not be evaded. In France under the ancient régime the tax on this article differed a good deal in the different provinces, but its transportation from one into another was prohibited. Its manufacture was also limited, and that which was produced by natural evaporation on the coasts was thrown back into the sea by the fiscal agents. While the price was enormous, the great majority of the citizens were not allowed to buy as small a quantity as they chose; they were compelled to pay for a certain amount conditioned upon the size of the family. On the other hand, certain privileged persons received all the salt they wanted gratis; or, if they preferred, they had the prerogative of receiving money in lieu thereof. The king did not directly control the salt monopoly. He acted through an association of revenue farmers who paid into the fisc a fixed sum, after which they had the legal right to exploit their helpless victims to the utmost. They possessed police powers and used them unmercifully. Evasions of the salt laws were rigorously punished by the judges, who were almost always hand in glove with the salt-farmers. Every year for nearly two centuries there were from two to three thousand arrests. Those who were found guilty were

subjected to fines, to the lash and to the galleys. In case of a second conviction they were sometimes hanged. The peasant was prohibited from using salt a second time. The brine from meat or fish had to be thrown away; it could not be used in the kitchen or taken to the stables for the cattle. It was illegal for any one to make salt from sea-water even for his own use, and equally illegal to water animals with natural brine. To prevent tanners and leather-dressers, who employed salt in their industries, from putting it to any other use the salt farmers often poisoned it. Owing to the large number of different governments in Germany and owing to some divergencies in matters of internal administration, one can not make a statement on this point that is applicable to the entire country. But in view of the strong inclination of many of the German monarchs to ape French customs, especially the bad ones, it is safe to say that the salt monopoly in the empire was quite as oppressive as in France. It may be added that on the whole the French peasant was not as badly treated as his German brother; the former first shook off much of the burden by drastic means from causes that need not be considered here. So late as 1840 a sort of salt conscription was enforced in Saxony which required each family to buy a certain quantity of it and prohibited its sale to a second party. In Prussia a similar regulation was abolished in 1816. Salt was a government monopoly in the greater part of Germany until 1867, as it still is in Austria, Italy and some other countries. In Austria all salt works belong to the government; such was also the case in some other south German states until recently. It likewise owns all salt-yielding territory. At present there is a general revenue law for the empire and a duty on the foreign product. It is therefore a good deal cheaper in the German than in the Austrian empire. While it is doubtful whether any article of consumption has so long afforded governments a means of oppressing their subjects as salt, and while its history makes an interesting though rather gruesome chapter in political economy, it is, nevertheless, unfair to judge the ruling powers of the past by contemporary standards. Until comparatively recent times economic laws were so little understood and rulers were always so hard pressed for money that they were constrained to resort to such measures for raising revenue as promised the largest and most certain returns. In the nature of the case a commodity in such demand as salt had to bear a disproportionate share of the public burdens. Cruel and inhuman methods of legal procedure were the order of the day, and those who suffered from it did not themselves know any better way of attaining the ends in view. It is greatly to the credit of the English people that their jury system did much to mitigate the penalties to which many a transgressor against the revenue laws as against other laws made himself liable. Though juries could not change the statutes, they

refused to convict when the penalty seemed too great for the offense.

The United States has never collected revenue from salt, but when provision was made by congress for the government of the Northwest Territory and for the sale of lands therein, it took care to reserve the salt licks, apparently fearing that they might be made a means of extortion to the consumers of this indispensable article of diet. One section of the act of congress reads:

> That a salt spring lying upon a creek which empties into the Scioto River, on the east side, together with as many contiguous sections as shall be equal to one township, and every other salt spring which may be discovered, together with the section of one mile square, which includes it, also four sections at the center of every township, containing each one mile square, that shall be reserved for the future disposal of the United States; but there shall be no reservation except for salt springs, in fractional townships, where the fraction is less than three fourths of a township.

We read of bloody battles between Germanic tribes for the possession of salt springs, and the inference is perfectly fair that the rumor of very few has come down to us by means of the written and the printed page. In the new world rival Indian tribes in like manner often contended fiercely for the same flowing treasure. Here too we find a repetition of the nomenclature of primitive Europe. There are several salt rivers in the states formed out of the Northwest Territory besides salt creeks, salt licks and other names, due to the presence of natural salt. The number is doubtless very much larger than the list given in the ordinary gazetteers, as the insignificant ones are not mentioned.

Although there are few regions in any part of the world in which there are neither saline springs nor deposits of rock-salt, it is probable that the Aryan name was derived from the sea and that the first salt was obtained from it by natural evaporation. In Homer *áls* means both salt and the sea; or perhaps it would be better to say that salt is named from the sea because the saline property of sea-water is its most salient characteristic. The designation *áls* is more particularly applied to that part of the sea which is near the land, as also to its bays and inlets, those parts with which man in the nature of the case was most familiar. In the Roman territory there existed in ancient times a Via Salaria, or Salt Road, which extended from the territory of the Sabines to the mouth of the Tiber, along which these people were permitted to transport salt for domestic use from the Mediterranean through the Roman country. The early Italians were, therefore, also dependent on the sea for their salt. It is noteworthy that Homer does not mention salt as employed in connection with sacrificial ceremonies. On the other hand, Virgil speaks of it as in regular use among the Romans, as do also other writers. While it is always

unsafe to base conclusions on the evidence of silence, another ancient author quoted by Athenaeus says that in former times the Greeks burned the sacrificial parts of animals without salt, and that the custom continued into later times in conformity with the ancient practise. Here then we have Homer's silence supplemented by positive testimony. It is well known, moreover, that all peoples are more conservative in religious usages than in any other. The adhibition of salt, the *mola salsa* of the Romans, seems not to have been borrowed from the Greeks, as were so many of their religious ceremonies. Like the Romans with their salted meal, the Hebrews were careful not to omit salt from their sacrifices, though the former may not regularly have put it on the flesh of the slain victims. In Leviticus we read: "And every oblation of thy meal offering thou shalt season with salt, neither shalt thou suffer the salt of the covenant of thy God to be lacking from thy meal offering: with all thine oblations thou shalt offer salt." From this command it may be inferred that salt was a part of bloody sacrifices as well as of those of the fruits of the earth.

In Germany there are many place-names that contain the Keltic root *hal* which seem in some way to be connected with sodium chloride. The best known of these is the city of Halle on the river bearing the Teutonic appellation, Saale. It is not easy to see how this double designation originated and conjectures are feeble arguments. There is no doubt, however, that Halle got its name from the salt springs near it. In the same country there were anciently several rivers called Sala on the banks of which salt works bearing the name Hall were planted. Besides the Halle already mentioned there is Reichenhall in Bavaria, Hallein in Salzburg, Hall in Tyrol and in Swabia, as also Halen in Brabant, and others. In Czech there are likewise a number of words containing the radical *hal* that have some connection with salt. This root is still distinctly preserved in the Welsh 'halen' salt. In some of the Keltic dialects, however, the initial h is represented by s.

In England there are a number of inland towns to the names of which the suffix wich, from the Norse *wic,* a bay, is appended. This seeming absurdity is easily understood when we remember that a wychhouse or wickhouse and a bayhouse came to be regarded as synonymous terms, and that wychhouses were erected where salt was prepared from brine, though they might be far from a bay. In the same way a coarse kind of salt came to be called baysalt from its similarity to the crude article of primitive manufacture. The wics in Essex were probably the first localities where salt works of the rude original type were erected. According to Isaac Taylor, the Domesday Book gives the names of three hundred and eighty-five places in Sussex alone where salt was made. The number seems incredible and may be a misprint; but the general fact is well established.

In Great Britain, as on the Continent, salt was obtained before the advent of the Teutons or the Romans. Here, too, we find our guide in the syllable '*hal,*' which occurs in place-names in Carnarvon, in Hampshire, in Lancaster and elsewhere. Plutarch has left upon record some evidence that points to a period when salt was practically unknown in Egypt. He says the priests will permit no salt upon their tables, will not address a pilot because of his occupation at sea, and that they also eschew fish for the same reason. Another passage seems to modify this strong statement to this extent that there are certain times when the priests do not partake of salt for the reason that it increases the desire for food and drink. All Greek evidence on such points is, however, of small value, since to the Greeks Egypt was at all times a wonderland where the most singular and unique customs prevailed. Long before Plutarch's time Herodotus reported to his countrymen that the people of the Nile valley did everything different from his own countrymen. A special ceremony or a custom observed only on particular occasions was easily perverted to a general usage by persons who had merely a superficial knowledge of the conditions.

Northern Africa has from time immemorial been a great storehouse of salt. Thebes in Egypt was the starting point for caravans that moved across it towards the west, perhaps as far as the Niger. Herodotus relates that a ten-day journey from the city heaps of the mineral lie in large lumps upon the hills and that from the tops of these hills salt water gushes forth. It is in this region that the Ammonians dwell, in whose district is the celebrated temple of Jupiter Ammon. The oasis is the bottom of what was once a salt lake or part of the sea and still has many salt springs in it. The soil is also impregnated with salt, although there is no scarcity of fresh water. It is probable that the chemical compound known as sal ammoniac gets its name from this region, either because it was first manufactured here or because it was found here in its natural state.

In many parts of northern Africa, often at long distances from the coast, salt occurs in great abundance. Though there is generally stone in plenty, the inhabitants in some places use blocks of salt for constructing dwellings, since it is easier handled and there is no danger to be apprehended from rain, which rarely falls in this part of the world. The salt blocks employed for this purpose are, however, not pure. They are cemented with mud, probably owing to a scarcity of lime. Some portions of the Sahara are covered with a crust of salt to such an extent as to give long reaches the appearance of being covered with a recent fall of snow. Some of the statements of Herodotus and other ancient writers are perhaps exaggerated, but many of them are corroborated by recent explorers. M. Dubois in his work, 'Timbuctoo the Mysterious,' affirms that salt is as highly valued as ever in

this part of the world, in spite of its great abundance. He found salt mines in the heart of the desert near a place called Thegazza. For the Soudanese salt has from time immemorial represented, and still represents, the principal article of commerce and their most precious commodity. The long depression in the western Sahara bearing the name of El Djouf is a vast mine of rock salt. The salt mines of Thegazza were abandoned in the sixteenth century for those of Taoudemi, nearer Timbuctoo. The same explorer reports that even here the houses are built of rock salt and roofed with camel skins. Under a thin covering of sand the mineral is found in clearly marked layers. It is dug out in large lumps and trimmed down to blocks about three and a half feet long by one and one fourth feet in breadth. It looks like bars of red or gray-veined marble, and as they come out of the mine they are stamped with the trade-mark of the different contractors. At Timbuctoo they are embellished with designs in black paint and the name of some venerated chief is written on them in Arabic characters. They are then bound round with thongs of raw leather so arranged as to hold the parts together in case of fracture. The densest and whitest blocks are most in demand, those veined with red being of an inferior quality. Timbuctoo is the entrepot of the whole region lying southeast as far as Lake Chad. There is nothing that the Soudanese possesses that he refuses to part with for a lump of salt. To these people it is more valuable than gold itself.

In ancient as well as modern times the partaking of salt with another person was regarded as the symbol of friendship and hospitality. Among the Slavic peoples it is still the custom to welcome the stranger with a proffered gift of salt and bread; while in cases of dispute the Arab is wont to appeal to the bread and salt he has eaten with his adversary as proof of sincerity. The advice embodied in the injunction, 'Before you make a friend, eat a bushel of salt with him,' has been proverbial from the remotest times. Both Aristotle and Cicero refer to it as current in their time. An ancient commentator on Homer says that salt is regarded as the symbol of friendship, *par excellence,* either because it was offered to guests before anything else, or because salt more than any other substance is a prophylactic against decay. In Numbers certain offerings are enumerated as constituting 'a covenant of salt for ever before the Lord unto thee and thy seed with thee.' Perhaps the custom of handing down the salt vessel from generation to generation in Roman families has some connection with the idea of incorruption.

The word *salt* has impressed itself on our language in a curious way in our term 'salary.' So necessary did the Romans consider salt to the efficiency of their armies that each soldier was provided with a special ration of it, or with the means of providing it. This stipend

was called *salarium argentum.* Civil officials or military officers when traveling in a civil capacity were also provided with this ration of salt. In later times, when the commodity was no longer difficult to obtain, money was paid in lieu of salt, but still ostensibly for the purpose of providing the same article. Generally, however, the allowance was sufficiently liberal to purchase a good many things besides sodium chloride. In time salt-money in ancient Rome came to be as comprehensive as 'stationery' in the phraseology of our home-grown legislators. The officials received no salary, yet the unfortunate provincials would generally have been glad to pay a definite amount rather than the presents (?) and perquisites which they were called upon to provide. A salary usually means a fixed sum, but there never has been framed a clear definition of 'necessary expenses.'

As indicated above, it is still a mooted question whether the consumption of salt is essential to the maintenance of animal life. If, as is now generally held, marine fauna antedated all others, it is reasonable to suppose that the principle of atavism would never carry living beings beyond a natural fondness for and even the necessity of consuming saline matter. On the other hand, it is maintained by some competent authorities that a sufficient quantity is taken into the system by the herbivora to supply all natural requirements. From these it passes into the bodies of the carnivora. Those who insist that sufficient salt is taken into the animal body indirectly with the food are equally positive that the excessive fondness for it exhibited by most men and some other animals is the result of a perverted taste. They cite as a parallel case the eagerness with which dogs and other brutes, to say nothing of human beings, devour sweetmeats, as evidence of a vitiated taste that readily results in more or less serious harm. Certain it is that no mineral substance has ever been so eagerly sought as an ingredient of food and it is probable that the quantity consumed is on the increase. But whether animal life is possible under conditions where salt is wholly absent can, in the present state of our knowledge, be neither categorically affirmed nor positively denied.

WALTER REED.*

BY MAJOR WALTER D. McCAW,

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IT is given to but few scientific men to lay bare a secret of nature materially affecting the prosperity of nations, and the lives, fortunes and happiness of thousands. Fewer still succeed in so quickly convincing brother scientists and men in authority of the truth of their discoveries that their own eyes behold the glorious result of their labor. Of the fifty-one years of Walter Reed's industrious, blameless life, twelve only were spent in the study of the special branch of science in which he became famous, but his name now stands with those of Jenner, Lister and Morton, as among the benefactors of humanity.

Walter Reed was born in Gloucester County, Virginia, September 13, 1851, the son of the Rev. Lemuel Sutton Reed and Pharaba White, his wife. The circumstances of his family were modest, and some of the years of his boyhood were spent in a much troubled section of the south during the great civil war. He acquired, however, a good preliminary education, and at an age when most boys are still in the schoolroom, he began the study of medicine at the University of Virginia, graduating as M.D. in 1868, when only seventeen years old. A second medical degree was received later from Bellevue Medical College, New York, and then came terms of service in the Brooklyn City Hospital, and the City Hospital, Blackwell's Island. Before the age of twenty-one, Reed was a district physician in New York City, and at twenty-two one of the five inspectors of the Board of Health of Brooklyn.

He entered the army of the United States as assistant surgeon with the rank of first lieutenant, in 1875, and for the next eighteen years, with the usual varying fortunes of a young medical officer of the army, he served in Arizona, Nebraska, Dakota and in the southern and eastern states. According to the exigencies of the service he was moved frequently from station to station, everywhere recognized by men of his own age as a charming and sympathetic companion, and by older officers as an earnest and intelligent physician, whose industry, fidelity to duty, and singularly clear judgment, gave brilliant promise for the future. In the poor cabins and dugouts of the pioneers in the sparsely settled districts where he served his flag, Reed was ever a messenger of healing and comfort. At that time army posts on the frontier were

* A memoir, published by the Walter Reed Memorial Association. Contributions to the memorial fund may be sent to the treasurer, Mr. Chas J. Bell, President American Security and Trust Co., Washington, D. C.

usually remote and with small garrisons. The young medical officer, generally the only one at the station, was called upon by the settlers for miles around. Without help, and with only such instruments and medicines as could be hastily stuffed in his saddle-bag, he was summoned to attend a fractured thigh, a child choking with diphtheria, or, most trying of all, a complicated child-birth.

Such experience schools well in self-reliance, and in the formation of quick and accurate observation. For a man like Reed, already an earnest student, no better preparation could perhaps have been had. His earlier army service must have singularly tended to develop in him the very qualities most necessary to his final success. To the end of his life it was noticeable that even when he had long given up the practice of medicine for the work of the laboratory, he was, nevertheless, unexcelled at the bedside for rapid unerring diagnosis and sound judgment in treatment. So also were the series of experiments which robbed yellow fever of its terrors especially remarkable for simplicity, accuracy and completeness, or they never would have so quickly convinced the world of their truth. Too much reverence for accepted teachings, and too little experience in grappling with difficulties unassisted, and they might never have been conceived or carried out.

In 1890, he was assigned to duty in Baltimore and remained there over a year. Here he had the great advantage of working in the laboratories of Johns Hopkins University and the happiness of winning the close friendship of his distinguished teacher, Professor William H. Welch.

In 1893 Reed was promoted surgeon with the rank of major, and in the same year was detailed in Washington as curator of the Army Medical Museum and professor of bacteriology at the newly organized Army Medical School. Here he worked industriously at his specialty and wrote many valuable monographs, all characterized by accuracy and originality. His excellent judgment made him especially valuable in investigating the causes of epidemic diseases at military posts and in making sanitary inspections. He was, therefore, frequently selected for such work, which, with his duties as teacher and member of examining boards, occupied much of the time that he would otherwise have spent in his laboratory. Here, again, it seems that duties which must often have been irksome were specially fitting him for his culminating work.

During the Spanish-American war the camps of the volunteer troops in the United States were devastated by typhoid fever, and Major Reed was selected as the head of a board to study the causation and spread of the disease. This immense task occupied more than a year's time. With the utmost patience and accuracy the details of hundreds of individual cases were grouped and studied. The report of the commission, now in course of publication by the government, is a monumental work which must always serve as a basis for future study

of the epidemiology of typhoid fever. The most original and valuable work of the board is the proof that the infection of typhoid fever is spread in camps by the common fly, and by contact with patients and infected articles, clothing, tentage and utensils, as well as by contaminated drinking water.

In June, 1900, Major Reed was sent to Cuba as president of a board to study the infectious diseases of the country, but more especially yellow fever. Associated with him were Acting Assistant Surgeons James Carroll, Jesse W. Lazear and A. Agramonte. At this time the American authorities in Cuba had for a year and a half endeavored to diminish the disease and mortality of the Cuban towns, by general sanitary work, but while the health of the population showed distinct improvement and the mortality had greatly diminished, yellow fever apparently had been entirely unaffected by these measures. In fact, owing to the large number of non-immune foreigners, the disease was more frequent than usual in Havana and in Quemados near the camp of American troops, and many valuable lives of American officers and soldiers had been lost.

Reed was convinced from the first that general sanitary measures alone would not check the disease, but that its transmission was probably due to an insect. The fact that malarial fever, caused by an animal parasite in the blood, is transmitted from man to man through the agency of certain mosquitoes had been recently accepted by the scientific world; also several years before, Dr. Carlos Finlay, of Havana, had advanced the theory that a mosquito conveyed the unknown cause of yellow fever, but did not succeed in demonstrating the truth of his theory.

Dr. H. R. Carter, of the Marine Hospital Service, had written a paper showing that although the period of incubation of yellow fever was only five days, yet a house to which a patient was carried did not become infected for from fifteen to twenty days. To Reed's mind this indicated that the unknown infective agent has to undergo a period of incubation of from ten to fifteen days, and probably in the body of a biting insect. 'Up to this time the most generally accepted theory as to the causation of yellow fever was that of Sanarelli, who claimed that the *Bacillus icteroides* discovered by him was the specific agent of the disease. Major Reed, in association with Dr. Carroll, had, however, already demonstrated that this bacillus was one widely disseminated in the United States, and bore no special relation to yellow fever.

In June, July and August, 1900, the commission gave their entire attention to the bacteriological study of the blood of yellow fever patients, and the post-mortem examination of the organs of those dying with the disease. In twenty-four cases where the blood was repeatedly examined, as well as in eleven carefully studied autopsies, *Bacillus icteroides* was not discovered, nor was there any indication of the presence in the blood of a specific cause of the disease.

Application was made to General Leonard Wood, the military governor of Cuba, for permission to conduct experiments on non-immune persons, and a liberal sum of money requested for the purpose of rewarding volunteers who would submit themselves to experiment. It was, indeed, fortunate that the military governor of Cuba was a man who by his breadth of mind and special scientific training could readily appreciate the arguments of Major Reed as to the value of the proposed work. Money and full authority to proceed were promptly granted, and to the everlasting glory of the American soldier, volunteers from the army offered themselves for experiment in plenty, and with the utmost fearlessness.

Before the arrangements were entirely completed, Dr. Carroll, a member of the commission, allowed himself to be bitten by a mosquito that twelve days previously had filled itself with the blood of a yellow fever patient. He suffered from a very severe attack, and his was the first experimental case. Dr. Lazear also experimented on himself at the same time, but was not infected. Some days later, while in the yellow fever ward, he was bitten by a mosquito and noted the fact carefully. He acquired the disease in its most terrible form and died a martyr to science, and a true hero. No other fatality occurred among the brave men who, in the course of the experiments, willingly exposed themselves to the infection of the dreaded disease.

A camp was especially constructed for the experiments about four miles from Havana, christened Camp Lazear in honor of the dead comrade. The inmates of the camp were put into most rigid quarantine and ample time was allowed to eliminate any possibility of the disease being brought in from Havana. The personnel consisted of three nurses and nine non-immunes, all in the military service, and included two physicians.

From time to time Spanish immigrants, newly arrived, were brought in directly from the immigrant station; a person not known to be immune was not allowed to leave camp, or if he did, was forbidded to return. The most complete record was kept of the health of every man to be experimented upon, thus eliminating the possibility of any other disease than yellow fever complicating the case.

The mosquitoes used were specially bred from the eggs and kept in a building screened by wire netting. When an insect was wanted for an experiment it was taken into a yellow fever hospital and allowed to fill itself with the blood of a patient; afterward at varying intervals from the time of this meal of blood it was purposely applied to non-immunes in camp. In December five cases of the disease were developed as the result of such applications; in January, three, and in February, two, making in all ten, exclusive of the cases of Drs. Carroll and Lazear. Immediately upon the appearance of the first recognized symptoms of the disease, in any one of these experimental cases, the patient was taken from Camp Lazear to a yellow fever hospital, one

mile distant. Every person in camp was rigidly protected from accidental mosquito bites, and not in a single instance did yellow fever develop in the camp, except at the will of the experimenters. The experiments were conducted at a season when there was the least chance of naturally acquiring the disease, and the mosquitoes used were kept active by maintaining them at a summer temperature.

A completely mosquito-proof building was divided into two compartments by a wire screen partition; infected insects were liberated on one side only. A brave non-immune entered and remained long enough to allow himself to be bitten several times. He was attacked by yellow fever, while two susceptible men in the other compartment did not acquire the disease, although sleeping there thirteen nights. This demonstrates in the simplest and most certain manner that the infectiousness of the building was due only to the presence of the insects.

Every attempt was made to infect individuals by means of bedding, clothes and other articles that had been used and soiled by patients suffering with virulent yellow fever. Volunteers slept in the room with and handled the most filthy articles for twenty nights, but not a symptom of yellow fever was noted among them, nor was their health in the slightest degree affected. Nevertheless, they were not immune to the disease, for some of them were afterward purposely infected by mosquito bites. This experiment indicates at once the uselessness of destroying valuable property for fear of infection. Had the people of the United States known this one fact a hundred years ago, an enormous amount of money would have been saved to householders.

Besides the experimental cases caused by mosquito bite, four non-immunes were infected by injecting blood drawn directly from the veins of yellow fever patients in the first two days of the disease, thus demonstrating the presence of an infectious agent in the blood at this early period of the attack. Even the blood serum of a patient, passed through a bacteria-proof filter, was found to be capable of causing yellow fever in another person.

The details of the experiments are most interesting, but it must here suffice to briefly sum up the principal conclusions of this admirable board of investigators of which Reed was the master mind:

1. The specific agent in the causation of yellow fever exists in the blood of a patient for the first three days of his attack, after which time he ceases to be a menace to the health of others.

2. A mosquito of a single species, *Stegomyia fasciata*, ingesting the blood of a patient during this infective period is powerless to convey the disease to another person by its bite until about twelve days have elapsed, but can do so thereafter for an indefinite period, probably during the remainder of its life.

3. The disease can not in nature be spread in any other way than

by the bite of the previously infected *Stegomyia*. Articles used and soiled by patients do not carry infection.

These conclusions pointed so clearly to the practical method of exterminating the disease that they were at once accepted by the sanitary authorities in Cuba, and put to the test in Havana, where for nearly a cenury and a half, by actual record, the disease had never failed to appear annually. In February, 1901, the chief sanitary officer in Havana, Major W. C. Gorgas, Medical Department, U. S. Army, instituted measures to eradicate the disease, based entirely on the conclusions of the commission. Cases of yellow fever were required to be reported as promptly as possible, the patient was at first rigidly isolated, and immediately upon the report a force of men from the sanitary department visited the house. All the rooms of the building and of the neighboring houses were sealed and fumigated to destroy the mosquitoes present. Window and door screens were put up, and after the death or recovery of the patient, his room was fumigated and every mosquito destroyed. A war of extermination was also waged against mosquitoes in general, and an energetic effort was made to diminish the number bred by draining standing water, screening tanks and vessels, using petroleum on water that could not be drained, and in the most systematic manner destroying the breeding places of the insects.

When the warm season returned a few cases occurred, but by September, 1901, the last case of yellow fever originated in Havana, since which time the city has been entirely exempt from the terrible disease, that had there kept stronghold for a hundred and fifty years. Cases are now admitted into Havana from Mexican ports, but are treated under screens with perfect impunity, in the ordinary city hospitals. The crusade against the insects also caused a very large decrease in malarial fevers.

The destruction of the most fatal epidemic disease of the western hemisphere, in its favorite home city is but the beginning of the benefit to mankind that may be expected to follow the work of Reed and his associates. There can be no manner of doubt should Mexico, Brazil and the Central American Republics, where the disease still exists, follow strictly the example set by Havana, that yellow fever will become extinct and the United States forever freed from the scourge, that has in the past slain thousands of our citizens and caused the loss of untold treasure.

More recent investigations into the cause and spread of yellow fever have only succeeded in verifying the work of Reed and his commission in every particular and in adding very little to our knowledge of the disease. Later researches by Guiteras in Havana, by the Public Health and Marine and Hospital Service in Vera Cruz, and lastly by a delegation from the Pasteur Institute of Paris in Rio de Janeiro, all confirm in the most convincing manner, both the accuracy and comprehensive-

ness of the conclusions of the American commission. It has been well said that Reed's experiments 'will always remain as models in the annals of scientific research, both for the exactness with which they were adapted to the points to be proved and the precautions taken that no experiment should be vitiated by failure to exclude all possible sources of error.'

Appreciation of Reed's work was instant in the scientific world. Honorary degrees from Harvard University and the University of Michigan were conferred upon him, learned societies and distinguished men delighted to honor him, and after his death congress voted a special pension to his widow.

To the United States the value of his services can not be estimated. Ninety times has yellow fever invaded the country, carrying death and destruction, leaving poverty and grief. New Orleans, Memphis, Charleston, Galveston, Portsmouth, Baltimore, Philadelphia, New York and many smaller towns have been swept by the disease. The epidemic of 1853 cost New Orleans eight thousand lives, that of 1793 wiped out ten per cent. of Philadelphia's population. The financial loss to the United States in the one epidemic of 1878 was estimated as amounting to fifteen million three hundred and thirty-five thousand dollars; but suffering, panic, fear and the tears of widows and orphans can never be estimated. Now, however, if yellow fever should again cross our southern border, there need be no disturbance of commerce or loss of property in the slightest degree comparable with that which epidemics in the past have caused.

The death of Major Reed took place November 23, 1902, in Washington, from appendicitis. It is gratifying to think that, although his country and the scientific world were deprived of one from whose future services more benefit to humanity might reasonably be expected, nevertheless he was privileged before his life's close to know that his discovery had been tested, and that a great city was freed from her ancient foe, to know that his conscientious work had contributed immeasurably toward the future prospects of an infant republic, and even more to the welfare of his own beloved country, whose flag he had served so faithfully.

In the national capital and in the great cities of the United States there are stately monuments to the country's great ones. Statues of warriors, statesmen and patriots stand as silent witnesses of a people's gratitude. Is there not room for the effigy of Walter Reed, who so clearly pointed out to his fellow man the way to conquer America's worst plague?

THE ROYAL PRUSSIAN ACADEMY OF SCIENCE AND THE FINE ARTS. BERLIN.

BY EDWARD F. WILLIAMS,

CHICAGO, ILL.

VI. *The History of the Academy under the Emperor William I., the Emperor Frederick III. and his son William II., the present Emperor, or from 1859 to 1900.*

AS early as 1860 A. Kirchhoff, in an address delivered on one of the festival days of the academy, emphasized the change which had been introduced into the methods of scientific study. Research, he said, had limited itself to narrow fields with a view to the mastery of the least important detail in them. This limitation he regarded as necessary. Although the academy had done its part in the discovery and confirmation of the law of the conservation of energy, and had shown the immense value of the law of evolution as a scientific hypothesis, the time had come when investigation must be content to confine itself to a limited field, if its results are to be trustworthy, and permit men of comprehensive minds and more general information to weave them into consistent philosophical systems. The era of the universal had passed, that of the particular had begun.

The Prince of Prussia, brother of the king, became regent in 1859 and king in 1860. He was succeeded by his son, Frederick III., who, after a reign of three months, was followed by his son William II., who is still on the throne. Each of these sovereigns has favored the academy so far as possible.

From 1859 to 1900, 82 members were received into the academy. Of the 46 actively engaged in its work in 1859, Rammelsberg and Mommsen alone were living in 1900. Of the 82 new members, 32 had died and 4 had moved from Berlin. The physical class had lost but 11 members, the historical 25. Of some of these members a few words may be permitted. Helmholtz, the discoverer of the law of the conservation of energy, has been thought in Germany worthy of a place by the side of Sir Isaac Newton. His works on optics, acoustics and the physiology of the nerves are known everywhere and are received as authority. Von Siemens is famous for his discoveries in electricity and the practical use he made of them. Virchow, and van't Hoff the chemist, still living, have brought the academy lasting fame. During

the period from 1860 to 1900 the names of nine eminent historians were on its books. Droysen, Duncker, Waitz, von Sybel, Wattenbach, Nitzsch, Weitszaecker, Lehmann, von Tretschke, the last named representing the school of Ranke, one of the most illustrious of the eminent historians Germany has produced. Olshausen and Roediger represented the Hebrew language and literature as well as that of Syria and Arabia, and Dillmann, in addition to a thorough knowledge of Hebrew and Arabic, was especially famous for his mastery of Ethiopic.

Prior to 1870 the income of the academy had been very inadequate, although private gifts from the king and grants from the government had enabled it to carry out to a successful conclusion several important enterprises. For scientific purposes it had never received from its own resources more than $2,300 in any single year. By a cabinet order, dated at Versailles, March 2, 1871, the Archeological Institute of Rome, through which so much has been accomplished, was made a state institution, brought into connection with the academy and put under its control. On May 16, 1874, its name was changed to that of The Imperial German Institute of Archeology, and a branch of it established in Athens for the study of Grecian antiquities. In 1875 an agreement was made with the academies in Vienna and Munich whereby each of them shares in the expense and direction of this archeological work. Through the generosity of the government in 1874 the academy was in a position to expend for science three times as much as formerly. The figures show that between 1877 and 1897 nearly $350,000 were set aside for scientific purposes alone. During the reign of William I. institutes were organized and equipped in connection with all the Prussian universities, and most of the other German universities, for the training, under the best skill at command, of young men for research in special fields of scientific study. In these institutes some of the most striking of recent discoveries have been made.

The academy made its interest in astronomy manifest in the part it had in expeditions for the study of the occultations of Venus, in magnetism and meteorology by two expeditions sent to the poles for the study of these branches of science. The king had long been interested in the geodetic institute and in archeological studies, in the society formed for the publication of the Dutch sources of history, and shortly before his death he had determined to aid the work which had been begun on the Monumenta Borussia. He had opened the archives of the state to historical students from every part of the world. He had taken a deep interest in the excavation at Olympia and Pergamon, through the results of which the academy and the nation acquired well-deserved fame.

While the academy had every reason to look for sympathy and assistance from the Emperor Frederick III. and his wife, an appeal

to his son, after the father's untimely death, was not in vain. Means for aid in making a new dictionary of the Latin language on the most extensive scale possible, and for other important enterprises, were asked for and granted. Toward the cost of the dictionary the academies in Munich, Göttingen, Leipzig and Vienna contribute and share in directing and furnishing the labor which must be done on it. It is estimated that this will extend over twenty years at least, and require the aid of a score of men. The headquarters of the work are at Munich. An edition of the works of Kant worthy his name has been published, another of the writings of William von Humboldt, another of the mathematical works of Weierstrass. A dictionary of the old Egyptian language has been planned, and work in gathering material for it, in which scholars from different countries are taking part, is now progressing. The value of the academy as a mediator in projecting and carrying out costly works is illustrated in the excavations at Olympia and Pergamon. For the former the sum of $75,000 was granted. The work was planned solely in the interests of scholarship, with the agreement that all articles of value discovered by the excavations should be the property of Greece and be left within its limits. Suggested by Professor Curtius, entrusted to the care of a man of his selection, the first spadeful of earth was turned on October 4, 1875, and six years later the last. The results astonished the learned world, and not less so those obtained at Pergamon.

Preparations for observing the occultations of Venus were begun by Minister von Muhler as early as 1869, and an expedition, at the cost of the academy, was sent to Luxor in 1874, and another to Punta Arenas in 1883. Both were under the direction of the astronomer Auwers, who has published the results of his discoveries in six volumes. In 1878 plans were laid for a proper celebration of the four hundredth anniversary of Luther's birth, and the academy, in carrying out the wishes of the king and of the nation, offered a prize for a perfect edition of the writings of the reformer prior to 1521. The prize was awarded to E. Henrici in 1880, and in June, 1883, arrangements were made for a complete and standard edition of all Luther's works.

The year 1874 is remembered by the academy as the year in which its income was so increased as to enable it to undertake enterprises previously beyond its reach and at the same time to assist individuals in work for which their private means were insufficient. This change in its affairs was happily emphasized by Mommsen in his speech in July, 1874. In it he said there is something more in the world than Latin and Greek, than the upheaval of mountains or than the counting of figures, important as the academy deems them. The academy is and must be a common meeting place for all men of science, and must show an interest in whatever men of science of any nationality may

do, and thus put an end to everything like narrowness or selfishness in one's own work. The academy, as has already been seen, had begun to act, as it has continued to do, as a mediator between the government, which has the funds for important enterprises, and the men who, though poor, have the ability successfully to carry them out. Hence it is that for a quarter of a century at least the academy has been able to direct most of the great scientific enterprises of Germany and has given impulse and needed assistance to private efforts in narrow and limited, yet important fields of research. The income, which increases nearly every year with gifts by will and from people interested in its work, in 1900 amounted to 213,462 Marks, a little more than $53,000. The income had averaged from 1897 to 1900 136,462 Marks, or a little more than $39,000. Since May, 1898, one third of the interest of the Frau Maria Elizabeth Wentzel-Heckmann foundation, or of a capital of 1,500,000 Marks, has been available for scientific enterprises of the first magnitude. At the death of Frau Heckmann the interest of the entire sum will be available for the spread of scientific knowledge. It is stipulated that the income shall not be limited to a single field. While the academy may suggest the field to which the money shall be given, its final disposal is in the hands of a commission composed of the cultus minister and six persons, three of whom are to be chosen by the academy every five years. Thus far the gift has furnished means for a dictionary of the German law language, justified the academy in beginning the publication of an edition of the oldest Greek writers, which will embrace not less than fifty volumes, and provided for the equipment of an expedition to German East Africa for the study of natural history. A good deal of money is expended every year for prizes, although these are less favored than formerly, and an increasing amount in aiding individuals in special work of importance.

Changes in some of the statutes of the academy were adopted on March 2, 1881, by which its efficiency has been very much increased. The number of general meetings was reduced one half and those of the classes and their sections increased one half. The number of active members was put at 54, 27 for each class. The foreign members were reduced from 16 to 10 for each class, and since 1882 reports, formerly published every month, are now published weekly. These reports are of the highest value and are indispensable to those who would keep abreast of the advance made by Germany in scientific, historical or philosophical studies. Active members are paid 900 Marks ($225) a year, and are expected to attend all the sessions of the academy and to undertake any work which the members of their class may lay upon them. Secretaries are paid twice as much and persons employed for a longer or shorter time for special service are paid as the academy may direct. The chemist, the botanist and the geologist receive a salary which will enable them to live in Berlin.

In 1897, in addition to the publication of memoirs prepared by the members of the academy and contained in the regular 'Proceedings,' and to the making of grants such as it had long been in the habit of making to aid individuals to publish or complete important works of their own, the academy found itself in a position to look toward enterprises which would call for large sums of money and for the labor of many years. To some of them brief reference may be made. It had already taken part in the founding and directing of the work of the Imperial German Archeological Society. The academy is also represented by three of its members, one of whom must be the presiding officer, on the Central Direction of the Monumenta Germaniae. As has been suggested, it helped to bring into existence the geodetic and meteorological institutes of Prussia and agreed to furnish its share of the cost of the new Latin and Egyptian dictionaries. It has already published complete and worthy editions of the works of Frederick the Great, Luther and Kant, in addition to those of specialists on subjects to which they had given years of labor. In 1888 it was instrumental in founding the Historical Institute in Rome, over which von Sybel presided for five years. This society has a directing secretary who lives in Rome, and is assisted in his work by two competent historical scholars, each of whom is permitted to have a helper. One of its first objects was to collect all the correspondence between the Roman Curia and the nuncios sent to Germany during the Reformation. Five volumes of this correspondence, with two other volumes ready for the press, had been published in 1899. This work has now been brought into affiliation with the Royal Archives, where it will be within the reach of all scholars. Efforts were made in 1893 to gather the papal decrees on all subjects brought before the Curia which concern Germany. These are to be carefully arranged and classified and will go back to the thirteenth century. Work began with the decrees of the first half of the fifteenth century. These decrees are found in seven special Roman archives. The government appropriated at first 60,000 Marks a year ($15,000) for four years, and has since repeated the grant. Beginning with 1897 the director of the institute has edited and published a magazine whose title, 'Sources out of Italian Libraries and Archives,' indicates its purpose and its value. Not only does the academy mediate between the Geodetic Institute at Potsdam and the government, it performs the same service for the Meteorological Institute, which is in close touch with the Royal Observatory for Astrophysics. Upon the collection of Latin inscriptions, of which Mommsen was editor till his death, more than $100,000 have been expended, all of which was obtained through the academy chiefly from the sovereign. On this work, which is nearly completed, Mr. Hirschfield has since 1885 been associated with Mommsen. In 1888 a commission

was appointed for the study of numismatics. It turned its attention first to the work of collecting the ancient coins of northern Greece. Mommsen so greatly appreciated this effort that he turned over to the academy the 28,000 Marks ($7,000) given him on the fiftieth anniversary of his professorship. Vol. I. appeared in 1898. In 1897 two volumes of a work on 'The Posography of the Time of the Roman Emperors' appeared. Mommsen suggested it and was chairman of a commission having it in charge.

The Fronto Commission, seeking to solve a problem proposed by Niebuhr, undertook the publication of the Theodosian Codex and with

F. E. D. SCHLEIERMACHER.

the proceeds of the Savigny fund the publication of what is called a 'Vocabularium juris prudentiæ Romanæ' has been begun. Between 1878 and 1888 a complete collection of Attic inscriptions was published, and in 1899, under the direction of Mr. Frakel, the printing of a treatise on the inscriptions found in the Peloponessus was started, and preparations were made for the printing of those of the islands, those of Lesbos, Nesos and Tenedos being ready at that time. On this work of gathering inscriptions, editing them and giving them to the world, the academy has been engaged more than eighty years. In 1891

it was decided by the academy that an edition worthy the respect of scholars of the Greek writers prior to Eusebius and apart from those whose works relate to the New Testament was greatly needed. The Vienna academy had published the Latin writings prior to the seventh century. The commission into whose hands the work was given in 1893 consisted of Mommsen, Diels, von Wilamowitz-Moellendorf, von Gebhardt, Loofs and Harnack. The cost of this publication will be met jointly from the income of the Frau Heckmann foundation and by the publishing house of J. Hinrich, Leipzig. It is confidently anticipated that in some of these writings questions will be answered like these:

B. G. Niebuhr.

'How did the church free herself from her early Palestinian society?' 'How did the Roman system arise?' 'How were Greek and Roman culture changed into Greek and Roman Christianity?' 'How did the church receive the middle age culture?' 'Why do the Greek and Roman churches look back to the fathers as their founders, and to these early periods as their classical periods?'

It was a special gift from Frederick William IV. which led the academy to edit and publish the works of Frederick the Great. Droysen

and Duncker proposed (1) that the state and fugitive writings of the king during the first decade of his reign should be collected and printed and (2) that there should be a supplement to the regular edition of his works. It was decided that first of all the political correspondence should appear. Brought down to 1765, this has filled twenty-five volumes, and it is not yet completed. The state writings from the beginning of the reign to the beginning of the Seven Years' War fill three volumes. Out of this undertaking has grown another, that of publishing the 'Acta Borussica,' through which the full history of the Prussian government during the eighteenth century will be given. As early

THEODOR MOMMSEN

as 1899 volumes I. and II. had appeared. When complete the work can not fail to be of immense value to every one interested in the development of Prussia. Researches relating to the history of Brandenburg and Prussia accompany the 'Acta.' These researches are carried on under the direction of the cultus minister and the academy. They have already resulted in the formation of a new school of Prussian historians. The income of the Frau Heckmann gift has rendered it possible to publish a scientific dictionary of the terms used in old

German law. Under the auspices of the academy the works of Jacobi, Dirrichlet, Steiner, Weierstrass and Kronecker will soon see the light. A comprehensive work, taking in the entire animal world, valuable for the unity of its plan and its accuracy has been prepared by Schulze. The income of the Humboldt fund has been expended for the most part on costly journeys undertaken for scientific purposes. Thus Hansel was absent in South America from 1863 to 1867, studying the pampas of Argentina, exploring the bone caves of southern Brazil and observing the remains of mammals. Schweinfurth, the botanist, devoted himself, first at his own cost, as early as 1863, to the study of the

HERMANN VON HELMHOLTZ.

flora of the Nile valley. He went as far as the borders of Abyssinia and the Soudan. On his second journey in 1868, for which he received aid from the academy, he explored Lake El Ghasel, the region round about Njam Njam and Monbutta botanically, geologically and anthropomorphically. He returned to Berlin in 1871 and the conclusions he formed from his studies on his travels are found in the 'Proceedings' of the academy for the years 1870–72. Buchholz, the zoologist, went to equatorial Africa in 1874, and sent home a vast amount

of valuable material for future study. In 1876 Hildebrandt went from Zanzibar to Kilimandjaro and Ndur Kenia; Sachs visited Venezuela in order to study the habits of electrical fishes, and the results of his studies were published by Du Bois Reymond and Nitsch. Fritsch in 1878 was sent to Micronesia to study the rapidly vanishing native races and gather as many as possible of the memorials of their habits and customs. He spent a year in Jaluit, visited several of the smaller islands, then went to New Zealand and New Guinea, and in 1882 brought back to Berlin many thousands of the specimens he had been sent out to obtain. In 1883 Guessfeldt went to the Andes, Arning to Hawaii, and the next year Schweinfurth was sent to examine the desert between the Nile and the Red Sea and report its geodetic and geographical conditions. In 1889 nearly 25,000 Marks were voted to Hensen in aid of an expedition he was preparing to send to Rio Janeiro for the study of sea life. Several naturalists accompanied him. He discovered what he called *planktons,* from which, according to a report made to the academy in 1890, sea life is sustained. To this expedition the king gave 70,000 Marks and other private gifts brought the amount up to 105,000 Marks. Between the years 1890 and 1898, Völkens was sent to Kilimandjaro to study botany; the zoologist von Voelzhow to Madagascar, and Platte, in the interest of the same science, to the coasts of Chili; Fritsch to New Zealand; the geologist Moericke to the Chilian Andes, and the geographer Dove to Africa.

Thus the academy has kept itself in close touch with all recent movements in science, as well as with the advance in literary or historical studies. It has not hesitated to begin work which must take a generation to finish, and of which few of its living members can hope to see the results. Intimately connected with the universities, many of its members, professors in the University of Berlin, enjoying the respect and favor of the reigning sovereign, embracing in its ranks some of the foremost men in science, philosophy and history now living, it has naturally become a center around which the best men of Germany have gathered, and to which the eyes of students, wherever they live, are constantly turning.

SHORTER ARTICLES AND DISCUSSION.

ALUMNA'S CHILDREN AGAIN.

An article in the May number of the Popular Science Monthly, entitled 'Alumna's Children,' was recently called to my attention by a woman who, though not a college graduate, is 'decidedly a schooled woman' and the mother of five girls. "I had planned," she said, "to let all my girls go to college, but I *do* want to be a grandmother some time."

For answer I heaped the anxious lady's lap with photographs, photographs of babies, babies large and small, babies masculine and feminine, asleep and awake, clean and dirty, elegantly dressed and not dressed at all, but every one a baby to exult over and all the children of my college friends.

Far be it from me to dispute the Massachusetts vital statistics, and farther yet to dissent from 'Alumna's' conclusion that girls in the 'larva stage' need an intelligent care which too few of them receive. But it is not that admirably sane and practical conclusion, nor yet the irrefutable official statistics forming the author's premise that strikes dismay to the mother of five and produces even in those less directly interested an uncomfortable impression of things being dreadfully wrong somewhere. No, it is that dismal array of tragic incidents drawn from the author's personal knowledge, and her consequent theory of causes for the officially vouched for 1.8. It seems only fair, then, to admit to consideration the personal experience of another alumna, an alumna of slightly later date, who may, from that very fact, be able to bring to the matter a slightly different point of view.

I, too, have known of just such brave struggles against physical odds as 'Alumna' reports. I, too, have known of heartrending defeat and dearly bought victory. But the women who have suffered them are not college women. Possibly my experience in this line with my college frends has been an exceptionally happy one, but in granting that possibility we must grant likewise that 'Alumna's' may have been exceptional as well. It is fair, therefore, to balance one against the other. I do not wonder that the mother of five was troubled by Alumna's article. It is obviously deeply sincere and genuinely thoughtful. But when I had read it I glanced up at the photograph of one of the sweetest, sanest mothers who ever presided wisely over the destinies of children, which shows her sitting on one end of a sea-saw with her baby in her lap, smiling up at four little redheads ranged in ascending scale at the other end of the board. Certainly neither college nor preparation for it has robbed of their dues her ten years of married life.

Naturally at this date I can tell of few such families, for most of the college women I know are younger than this one. It is only a few years since my graduation, and three quarters of the class are still unmarried. But all except a few predestined spinsters are still well on the youthful side of thirty, and the percentage of married members is likely to be considerably raised in the next ten years. And of those who are married not only in my own class, but, with a single exception, among my other college friends as well, not one has failed to bear a healthy child within two years of her marriage.

Naturally it is of my own class that I think first, the class whose average scholarship is the highest on the rec-

ords of our *alma mater*, the class who did not use each other's christian names in the freshman year and never walked the halls in embracing couples, incurring thereby a reputation for utter lack of sentiment. But the bond that held us was all the stronger for not being flaunted abroad, and the children of the married members are all 'our babies.'

I put down the magazine and thought of our 'class baby,' our first born, with her splendid, sturdy little body and equally sturdy and independent mind. Not only her mother but her grandmother as well is a product—and a notable one—of the higher education, yet our class baby already possesses a baby brother, two years younger than herself and equally a model of physical and mental health.

Then came a picture of another of 'our babies,' 'the adorable,' with his sunny locks, his starry eyes and his gleesome laugh, always on tap. I thought of his mother as I used to see her crossing the campus, with her fine, high-bred face, her superb carriage and the movement that not even modern draperies could disguise, the very lines of bouyant grace which the 'Winged Victory' has made so familiar.

Then my thoughts strayed to our 'new baby,' the little daughter born in the west with two philosophers for parents and fair 'Mistress Wisdom' herself for godmother. The mother writes: 'My nurse says that health like mine is a thing to be conceited over,' and I know she will meet all the problems of wifehood and motherhood with the same serene clearsightedness that earned her college nickname of 'the Philosopher.'

Two others among my pictures I must mention, amateur photographs both, of sleeping babies. T— was about a year old when that was taken—tousled curls crushed on the pillow, lashes sweeping the rounded cheeks, soft pouting lips, bare dimpled arm and sleep-curled fingers—sweet tranquility and health breathing from every line of the relaxed little figure.

The other is the picture of a wee girl, just a week old. Her mother was the best biologist among the undergraduates of her college. This tiny maid and her sister two years older have spent all their long summers, both before and after birth, in a secluded camp on an Adirondack river shore and something of the woodland influence has entered into their being. They are as shy as young partridges—and as near to nature.

Now the question naturally arises whether the difference between my experience and that of 'alumna' is an accident, or whether it can be explained by a consistent theory. One suggests itself to me which may or may not be correct, that the difference is due to the different *kind* of girl who is going to college now. Only a short decade ago women's colleges drew practically all their students from what might be called the abnormally intellectual class. The girl who went to college, whether rich or poor, whether struggling to escape the demands of society life, or to scrape together money enough for her tuition, was the girl who made matters intellectual of paramount importance and was ready to sacrifice for them, from the grammar school up. College was either an outlet for insatiable mental activity or a technical preparation for the teacher. To girls of that sort domestic life was not imperatively attractive, a fact which may have some bearing on the low marriage rate. And when a woman of this type did marry she was too apt to furnish just such a woeful example as those cited in 'Alumna's' article.

It was the author of 'Harvard Stories,' I believe, who aptly classified all students, as 'grinds, sports—and just boys.' The 'just girl' was for a long time in the minority at women's colleges, but happily she is no longer so. On the contrary she is rapidly securing an overwhelming majority. 'Just girl' she is, 'just woman' she

will be, and the four years of college life is beginning to assume its proper place in public estimation. To produce, not phenomenal scholars nor well-equipped teachers, but fine, strong, human women—that is the function of those precious four years.

Again I turn to my own class—and as I run down the familiar roll from B to W and glance back over the nine years that have made those names part of my life, I see that somewhere, somehow, among the jumble of 'prescribed' and 'elective' courses, we learned therewith the better things, to see largely, to judge temperately, to choose true values. They look but chilly infinitives, written so, but the class knows how they have wrought into the very fiber of our lives and made us the women that we are. And more and more, as the true function of college life becomes recognized, as popular expectation ceases to demand in justification of a B.A. anything but 'just woman,' the type which couples intellectual attainment with underdeveloped body will disappear. For some years the importance of proper attention to the physical well-being of school children of both sexes has been impressing itself upon the public, and no one will apply scientific principles to the nurture of her children more intelligently and with less danger of capricious 'fads' than the college bred mother. We do 'want more' of alumnae's children, and we are going to get them—an efficient and cumulative force toward those wide and beneficent ends which all true culture stands for.

ANOTHER ALUMNA.

THE PROGRESS OF SCIENCE.

THE SANITARIAN AND THE POPULAR SCIENCE MONTHLY.

The *Sanitarian*, established in 1873, and The Popular Science Monthly, established in 1872, are the two oldest journals in English devoted to the diffusion and popularization of science. When the *Sanitarian* was founded there was no journal occupied with sanitary science and public health, and the attention paid to these subjects was comparatively small. The *Sanitarian* has witnessed and promoted one of the most important movements of the nineteenth century. There is more accomplished now for the prevention of disease than for the cure of disease. The 'germ theory' and other discoveries of modern science have led to the forging of weapons more powerful than those used in any other warfare. The mortality of infancy and childhood has been reduced to one half. Infection and contagion are subject to control. The plague, malaria, yellow fever, even consumption, have lost their mysterious terror. We know their causes and can set bounds to their ravages.

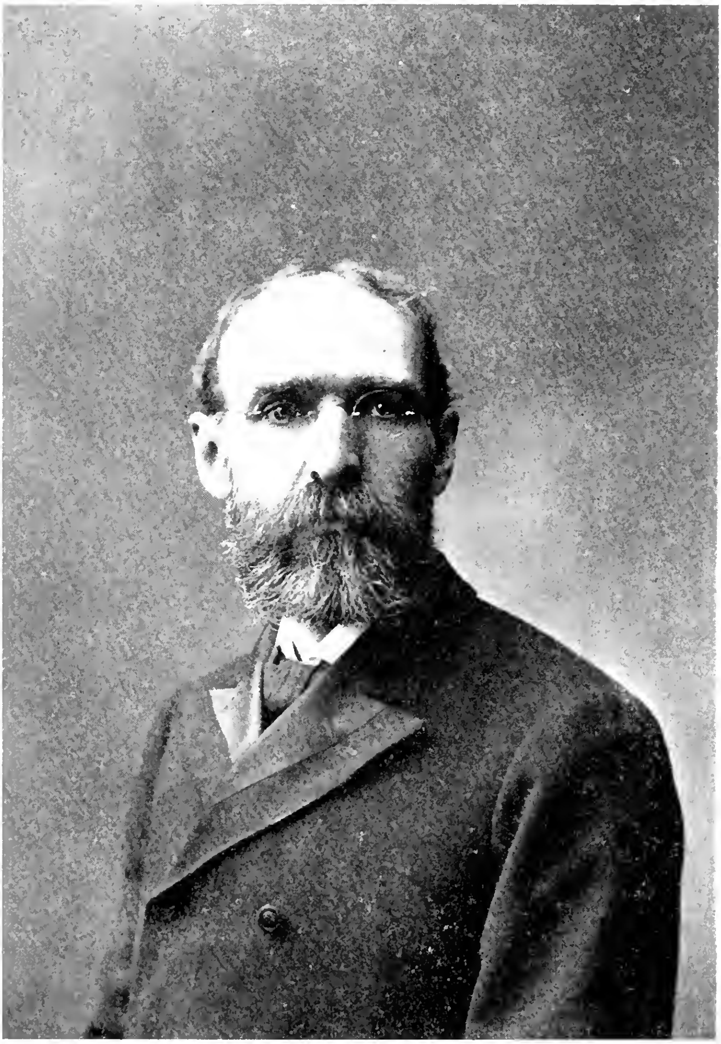
The *Sanitarian* was established by Dr. A. N. Bell, and has been conducted by him for thirty-one years. Dr. Bell is now in his eighty-fourth year, and though vigorous in mind and body, he has earned the right to rest from the labor of conducting a monthly journal. As there are now in the country numerous medical and other journals which give adequate attention to sanitary service and preventive medicine, it has seemed to Dr. Bell that the cause which he has served can be best advanced by merging the *Sanitarian* with The Popular Science Monthly. While the Monthly is concerned with all the sciences, it has always aimed to pay special attention to the important field of preventive medicine, and should do so more effectively in the future with the support of the editor, contributors and readers of the *Sanitarian*.

Dr. Bell has assured his reputation not only by the fifty-two volumes of the *Sanitarian*, but also by many other services tending to promote the health of the people. He was born in Virginia on August 3, 1820, and studied at the Harvard Medical School and the Jefferson Medical College. He became surgeon in the navy in 1847, and by services in the Gulf of Mexico, the West Indies and the coast of Africa he became familiar with yellow fever and other diseases. In 1847 he first used steam as a disinfectant, and he early urged the view that yellow fever is not directly contagious, thus greatly simplifying and improving quarantine regulations. As physician, as quarantine officer, as author and as editor, Dr. Bell has earned the gratitude and esteem of all who are interested in the health and welfare of the community.

THE JUBILEE OF THE UNIVERSITY OF WISCONSIN.

The University of Wisconsin celebrated during the second week in June its fiftieth anniversary and at the same time President Van Hise was formally installed. Michigan, California and Wisconsin form a group of universities which almost rank with Harvard, Yale and Columbia. The great state universities are indeed the more distinctively American, and it is quite possible that the future belongs to them. Millionaires may become less liberal in their gifts, whereas the people of a state are likely to take increasing


A N Bell M D
In his 84 Year



Charles R. Van Hise,
President of the University of Wisconsin.

pride in their university. As the alumni become prominent in public life the relations between the state and the university will be even more intimate. So long as a state university deserves support by the direct appeal it makes to the people there is no limit to its development. The milk-test invented by Professor Babcock, of the University of Wisconsin, saves the people of the state annually more than their university costs them. As soon as it is generally understood that a university is an asset, not a charge, our state universities may become the greatest existing centers for education and research.

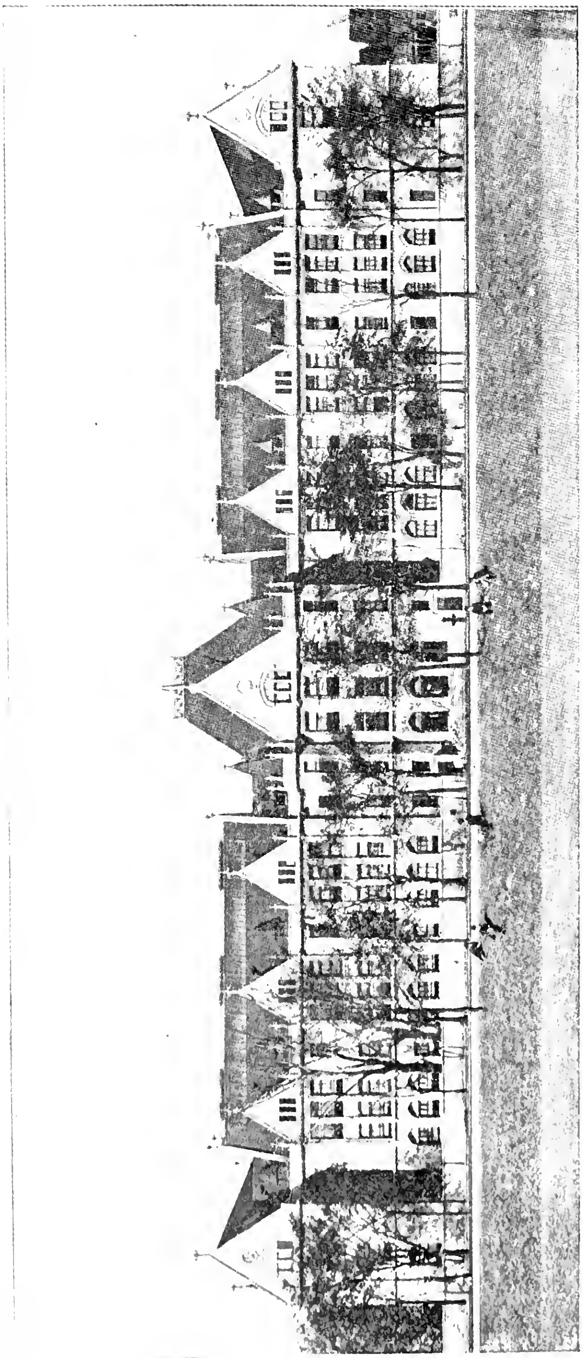
The University of Wisconsin is as a

matter of fact more than fifty years old. In 1838 an act was passed by the territorial legislature establishing the University of the Territory of Wisconsin. Practically nothing was done until the state was organized in 1848, when the university was established by the constitution. In 1866 the university was reorganized by act of the legislature, which also provided for uniting with the university the College of Agriculture, endowed with the proceeds of the agricultural college grant given by the United States in 1862. In 1867 the first annual appropriation (about $7,000) was made by the state. This appropriation has been gradually increased to about $300,000. The state has also provided a great group of fifteen or twenty buildings which are beautifully placed on the shore of Lake Mendota. The library building, used also by the State Historical Society and erected at a cost of over $600,000, is the finest academic building of the kind except that of Columbia. The students number over 3,000, about as many as Yale, Oxford or Leipzig.

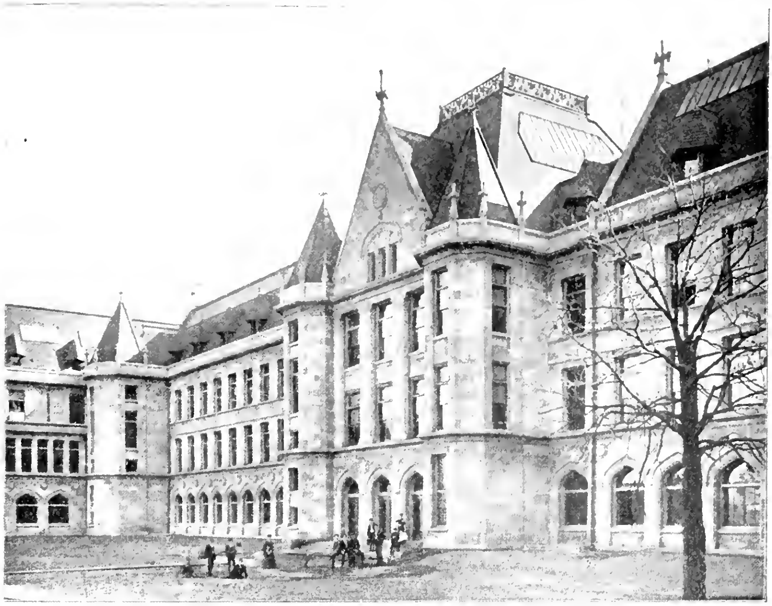
Over this great university one of its own graduates and professors will henceforth preside. Dr. Charles Richard Van Hise was born in Wisconsin in 1857 and has been connected with the university since he entered as a student nearly thirty years ago. He is one of the most eminent American geologists, in charge of the pre-Cambrian and metamorphic geology for the U. S. Geological Survey and a member of the National Academy of Sciences. Some years since when Columbia and Pennsylvania elected business men to the presidency, it looked as though scholarship might be subordinated to wealth and commercial success in this office. But Stanford chose a zoologist, Chicago a Semitic scholar, Yale an economist, Princeton a historian, California a student of Greek, Johns Hopkins a chemist and Columbia a student of education. Now Wisconsin has selected a man of science, one whose interests and character are far removed from politics or commercialism, an ideal scholar.

THE CHICAGO SCHOOL OF EDUCATION.

The Emmons Blaine Hall of the School of Education of the University of Chicago was dedicated on May 14. This was an event of importance in the history of education and the extension of scientific methods, for it is a step toward making teaching a profession and education an applied science. The University of Chicago has now established a school of education ranking with the professional schools of law and medicine, the first school of this kind being the Teachers College of Columbia University. There are other schools of education and nearly all the larger universities have established departments of education, but Columbia and Chicago are the universities that are leading the way. The two schools had beginnings somewhat analogous. In both cases independent movements for manual training and the less formal education of children have been subsequently taken over by the universities and made into professional schools for teachers with model schools for children attached. Dr. Nicholas Murray Butler, now president of Columbia University, was the first president and practically the founder of Teachers College, now the Department of Education of Columbia University, and it is especially appropriate that he should have given the oration at the dedication of the Emmons Blaine Hall. Other addresses were made by President Harper, of the University of Chicago; Dr. Jackman, dean of the College of Education; Mr. Bentley, of the Chicago Institute trustees; President Downing, of the New York City Normal College, representing the normal schools of the country; Mrs. Blaine, the donor of the hall, and Professor Dewey, director of the School of Education and head of the Department of Philosophy and



Emmons Blaine Hall, School of Education, as seen from the University.



EMMONS BLAINE HALL FROM SCAMMON COURT.

Education of the university. There were also additional addresses and departmental conferences in connection with the dedication of the building.

In their addresses President Harper and Dr. Jackman traced the history of the school, the former concluding with these words: "And so it has come about that in each case two agencies have united with each other; and that finally all six have been drawn together. These were Colonel Francis W. Parker with his faculty, and joined with them the sympathy and interest of Mrs. Emmons Blaine; the work of the Chicago Manual Training School under Mr. Belfield, and with it that of the South Side Academy, developed under the leadership of Mr. Owen; and, finally, the creative work of Mr. Dewey in his Laboratory School, and in connection with this the factor represented by the university itself. The history of these several movements and of their union with one another has been one of peculiar interest. Many difficulties have presented themselves from time to time, but one by one these difficulties have disappeared. What this school, made up thus of many elements, shall in the end contribute to the cause of education no man can predict. We may hope, however, that the results will be in proportion to the earnest effort thus far put forth by the many who have had at heart the sacredness of the cause. In so far as the school shall represent true ideals, it will help on the work. No more than this could be expected: no more than this could be asked for. The names of Colonel Parker, Mrs. Emmons Blaine, Mr. Belfield, Mr. Owen and Mr. Dewey are written in large letters on the foundation stones of this new structure."

Education and philosophy at Chicago suffer a serious loss by the removal of Professor Dewey to Columbia University. But the work that he has accomplished at Chicago remains; it has sufficient vitality to create its own leaders.

SCIENTIFIC ITEMS.

We record with regret the death of Professor E. J. Marey, the eminent French physiologist; of Dr. Wilhelm Hiss, professor of anatomy at Leipzig; of Mr. Robert McLachlan, the well-known British entomologist; of Dr. George Johnston Allman, professor of mathematics in Queen's College, Galway; of Wilhelm von Siemens, the German electrical engineer, and of Professor William Henry Pettee, professor of mineralogy, economic geology and mining at the Universty of Michigan.

At the jubilee celebrations of the University of Wisconsin the degree of Doctor of Laws was conferred on a number of delegates, including Henry Prentiss Armsby, director of the Pennsylvania Agricultural Experiment Station; Thomas C. Chamberlin, professor of geology, Unversity of Chicago; Professor W. G. Farlow, professor of botany, Harvard University; Daniel Coit Gilman, president of Carnegie Institution; the Hon. James Wilson, secretary of agriculture; Robert S. Woodward, dean of the faculty of pure science, Columbia University; F. P. Mall, professor of anatomy, Johns Hopkins University; E. L. Mark, professor of anatomy, Harvard University, and S. L. Penfield, professor of mineralogy, Yale University.

Professor Charles S. Howe was inaugurated as president of Case School of Applied Science, at Cleveland, Ohio, on May 11. President Ira Remsen, of Johns Hopkins University, spoke on behalf of the universities; President H. S. Pritchett, of the Massachusetts Institute of Technology, on behalf of the technical schools; John R. Freeman, of the American Society of Mechanical Engineers, on behalf of the technical societies; and President Charles Franklin Thwing, of Western Reserve University, on behalf of the colleges of Ohio. President Howe's inaugural address followed. Mr. John D. Rockefeller has given the Case School $200,-000 to be used for building and equipping laboratories for physics and mining engineering.

Columbia University has conferred its doctorate of science on Professor Hugo de Vries, the eminent botanist of the University of Amsterdam, whose work on the origin of species is described in the present number of the Monthly.—The American Academy of Arts and Sciences has awarded the Rumford medal to Professor E. F. Nichols, of Columbia University, for his researches on radiation.—The Chemical Society of London has elected as foreign members Professor E. W. Morley, of the Western Reserve University; and Professor F. W. Clarke, of the U. S. Geological Survey.

The new medical laboratories of the University of Pennsylvania, erected at a cost of $700,000, were dedicated on June 10.—The New York legislature has appropriated $250,000 for the erection of a building for the College of Agriculture at Cornell University.—The main building of the Rensselaer Polytechnic Institute, Troy, N. Y., was destroyed by fire on June 9.—The corporation of the Massachusetts Institute of Technology voted that the executive committee ascertain whether any arrangement can be made with Harvard University for a combination of effort in technical education such as will substantially preserve the organization, control, traditions and name of the Massachusetts Institute of Technology.

THE POPULAR SCIENCE MONTHLY.

AUGUST, 1904.

THE CONFLICT OF RELIGION AND SCIENCE.

BY EDWARD S. HOLDEN, Sc.D., LL.D.,

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"*Though all the winds of Doctrine were let loose to play upon the Earth, so Truth be in the field we do injuriously . . . to misdoubt her strength. Let her and falsehood grapple, who ever knew Truth put to the worse in a free and open encounter?*"—(Milton—*Areopagitica*).

THERE are many books that deal specifically with a supposed conflict between religion and science, or with a warfare between science and dogmatic theology. It is my conviction that the view-point of most books of the sort is badly chosen, and I desire in this preface to set forth briefly the reasons for thinking that the battle has often been joined on a wrong issue. The question is fundamental and deserves a much fuller treatment than can here be given. To make it entirely clear it might be necessary to reprint one of the warfare-of-science books with a commentary, meeting every argument as it arises; exhibiting and enforcing a different point of view; and proving that the change of view-point was reasonable and necessary. Lacking the space for extended argument, it is necessary to condense it. Indulgence is asked for a presentation that must necessarily be brief, but which can very readily be made more complete.

The mass of men believe that religion has come out vanquished, humiliated and discredited from a long warfare with triumphant science. One of the very wisest of 'the martyrs of science'—Roger Bacon—has said 'what the mass of men believe is necessarily false.' The saying is harsh, and Bacon suffered for it. It is more true to say that few popular formulas are so exactly stated that a historian of science can accept them in their crude and current form. The popular doctrine as to the conflict in question undoubtedly needs amending.

Most books of the warfare-of-science sort are built more or less on the same plan. Let us take the case of the figure of the earth for an example. They often treat it in the following order: The primitive conception, that of a flat earth; early scientific ideas of its sphericity; opposition of the early church; evolution of a sacred theory drawn from the Bible; its influence on christian thought; survival of the idea of a spherical earth; contrast of the theological and scientific spirit; last outbursts of theological hostility; retreat of the church; final triumph of science over theology. Or, more briefly, their treatment may often be summarized thus: Science always right; theology always interfering; glory to us who have done away with superstition!

The real conflict of the ages has been between enlightenment and ignorance. Sometimes the battle has been in the field of theology; sometimes it has been in the field of science. The warfare has nearly always been between religion and heresy; or between science and pseudo-science; occasionally, but not very often, between religion and pseudo (or it may sometimes be true) science. Usually, however, the fields were plainly marked off. The theologians of any one epoch treated theological questions and only those. They were not even interested in scientific questions, as such. Men of science, before the time of Galileo and Bruno, did not meddle with religion. Each class kept to its own sphere.

But let us return to the question of the figure of the earth. Untutored man believed the earth to be flat; the sky to hang above it like a canopy; the stars to be fixed to the canopy (or to hang from it as the Arabs taught); the canopy to move from rising to setting, from east to west. Now, this was an entirely scientific theory. It accounted satisfactorily for every fact known to untutored man. A theory is perfect when a future phenomenon can be predicted beforehand as accurately as it can subsequently be observed. This was then, at the time, a perfect theory; it needed no apologies. Aristarchus and other Greeks saw that the observed phenomena (rising and setting of the stars) could be as well explained by a spherical earth that turned on its axis—as well, but no better. They did not know which theory was true. They had no means of deciding the point.

A matter of importance must be here alluded to. Long centuries of experience have taught us that there is one and only one solution to a scientific problem. We call such a unique solution a 'theory.' Anything less definite is a provisional 'hypothesis.' Now, the theories of the ancients were generally held by them primarily as hypotheses. Their whole attitude towards certainty was, in physical science, entirely different from ours. It has required all the centuries to teach us our lesson of implicit trust in scientific methods. Our trust is, in fact, in methods, not, primarily, in results. In general, a physical theory attributed to one of the ancients was held by him as we hold a hypothesis. It

might be so; it probably was so; but he was not ready to die for it.

The early fathers of the christian church took some one view, some another, of the shape of the earth. St. Augustine tolerated the scientific view, and said at the same time: "What concern is it to me [as a theologian, he meant] whether the heavens as a sphere enclose the earth at the middle of the world, or overhang it on either side?" It was a matter of almost no concern to the Bishop of Hippo at that time, in that place, under those conditions. The mission of the church in the fifth century was to civilize the teeming millions of pagans and barbarians. It was a mighty task. It was performed. It required the entire energy of all churchmen. It was of infinitely small importance, then, whether the barbarians were crowded together on a flat or on a spherical earth. The entire indifference of churchmen, then and later, to purely scientific matters is a fact to be kept in mind.

The theory of a flat earth was enforced from scripture in the sixth century by an Egyptian monk and traveler, Cosmas Indicopleustes. The warfare-of-science books all treat his theory as monkish (because it is wrong). But he was a great traveler and he was reputed scientific in his time. His theory agreed well enough with the simpler facts as he knew them, although it can not stand a moment in face of the facts as they are. Are we to blame him for ignorance? If so, who shall 'scape whipping? Is it a merit of ours that we happen to have been born since 1521, when Magellan's voyage of circumnavigation was completed?

The books in question tickle our vanity with a suggestion that our fortune of birth is somehow a merit. Our children 'know' that the earth is round; that England is an island. How? Because they have been told so. It rests on authority for them. Their elders have a better basis for belief. They know how to prove or to disprove these assertions. But how many of the elders can *prove* that the earth turns on its axis? It is not an easy matter, and here, in their turn, they rest on authority. How many of my readers can describe Foucault's pendulum experiment off-hand, or explain how a change of gravity with the latitude demonstrates the earth's rotation? Our predecessors in the middle ages rested on the best authority they could attain. Are they to be blamed because our centuries of experience were not behind them?

The implied conclusion of the warfare-books seems to be that our predecessors are to be blamed for lack of open-mindedness to scientific truths. Open-mindedness implies long experience. It is a product of past centuries. Until the centuries are, in fact, past, this virtue can not be evolved; nor can its opposite vice be atrophied except by time.

It is a pertinent fact that in the seventh century Isidore of Seville,

and in the eighth the venerable Bede, pronounced in favor of the earth's sphericity. After these two great doctors had spoken it was allowable for any churchman to follow them. That many did not is an incident in the warfare with ignorance, not an attack of religion upon science; and this conclusion is a point to be emphasized.

Lightfoot, vice-chancellor of the University of Cambridge, in the seventeenth century, declared that the scriptures taught that 'heaven and earth, center and circumference, were created all together, in the same instant,' and that 'this work took place and man was created by the Trinity on October 23, 4004 B. C., at nine o'clock in the morning.' It has been appositely remarked that a crowd of busy men, who had invented geometry and other sciences, were busily engaged in building pyramids in Egypt on this very October morning. The Bible does not explicitly give the foregoing, or any, date. If it did so, we might have a conflict between science and the Bible. Archbishop Usher in 1650 fixed a date by interpreting the Biblical words scientifically (not theologically). His scientific methods will not stand examination. Any modern Biblical scholar can show this. Have we here any signs of a conflict between religion and science? Not at all. In a scientific question a mistaken method was employed then, as so many times before and since. That an erroneous scientific result had a bearing on theological matters was incidental, not essential. The wild disorder of Jordano Bruno's systems of cosmic infinities, notably his guess that the stars were worlds, filled the mind of Kepler with horror. He expressly says that he shuddered with horror at the thought. It was precisely these new infinities of worlds that the Roman inquisitors found to be heretical. They had, without knowing it, the support of the great protestant astronomer. Kepler's horror for Bruno's ideas was no theological opposition. It was based on the best philosophy of the time. Like the Roman inquisitors, Kepler believed the universe to be finite. Can we wonder that the fugitive Dominican monk was tried and sentenced for heresy? Can we wonder that ideas from which the free-minded speculative Kepler recoiled were odious to a congregation of monks?

The cases so far examined are typical. Nearly every recorded instance of 'conflict' can be reduced to one or another of them. All are explicable as conflicts primarily with ignorance—and in that way alone.

Dante declared that hell was beneath the earth. Medieval text-books answered the question: 'Why is the sun so red at sunset?' by declaring: 'because he looketh down upon hell.' This answer we know to be absurd; we even feel a flush of superiority to Dante and the middle age when the question is quoted; it is, apparently, sometimes quoted by the warfare-of-science books to produce this grateful glow; but not half the readers of this article can at once say what the

real answer is. The reply could not be completely given by any one until after the invention of the spectroscope in 1861—some forty years ago.

Copernicus taught the heliocentric theory—that the planets revolved about the sun, as we know that they do. In 1616 his books were placed upon the index, there to remain 'until corrected.' The action of the Congregation of the Index was an incident in the distressing history of Galileo. It was not taken, however, until the congregation had consulted leading astronomers and had obtained their verdict that the heliocentric theory was without foundation.* The pseudo-science of the Aristotelian professors (nearly all of whom were inimical to Galileo for personal as well as philosophical reasons) was opposed to the science of Copernicus. With this verdict in their minds it is not strange that the congregation should have proceeded against Galileo for heresy.

The system of Copernicus was proposed in 1543. It was true in its grand outlines; it was erroneous in many details. It was not *proved* till Galileo's discoveries of 1610. Tycho Brahé, the greatest authority of his time, expressly rejected it as absurd, and proposed a new system of the world in 1587. Kepler rejected Tycho's system and proposed his own first system (which was entirely erroneous) in 1597. He proposed his second system in 1609. How could theological doctors know that at last Kepler had reached the true system of the world by his glorious discoveries of 1609? His first theory was utterly without foundation. How could theologians, his contemporaries, possibly know that the second was not in like case? How could they know that he would not live to produce a third? Let us put ourselves in their place. What should we, being doctors of the church, ignorant of physical science, and profoundly indifferent to science as such, have done? Is it too much to conclude that our action would have been precisely that of the churchmen of that day? That we should have done precisely as the Romans did; as Luther, Melancthon and other protestants had earlier done? Kepler believed that all comets moved in straight lines; that the planets were sometimes repelled, sometimes attracted, by the sun; that each planet had a soul to guide it on its path; that all the planets sang together—Mercury, soprano; Venus, contralto; Mars, tenor; Jupiter and Saturn, bass. How much of all this was the church bound to accept? All of it is false. How could theological doctors possibly sift the false from the true?

The correspondence of Kepler and Galileo on the question of the tides is interesting in this connection. Kepler likens the earth to an animal, and the tides to its breathings and inbreathings, and says they follow the moon. Galileo laughs at him for this and declares that it is mere superstition to connect the moon with the tides. Ought the Roman church to have accepted Galileo's dictum?

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* This fact is omitted by the warfare-of-science books.

Let us, in order to make the whole question clearer, hark back to the middle ages. Contrasts are more strongly shown in their uncertain light. The thirteenth century possessed two thoroughly complete systems of science. One of them was worked out by Albertus Magnus with profound learning and at great length. It was a presentation of all the knowledge of the ancients enriched by the observations of the author. It was full of novelties. It stimulated, interested and instructed, and was in no important respect antagonistic to the current beliefs of his time. It was expounded, too, in a manner that inspired respect and won friendly recognition. The system of Roger Bacon was, on the other hand, hardy and original. It was set forth with a harsh arrogance that offended all the minds it was intended to convince. It was filled with diatribes against the pope, the cardinals, the Franciscans, the Dominicans, the clergy, the laity. It convicted Aristotle and the ancients of many faults. It pointed out errors in the writings of the fathers of the church and in the Vulgate. It exalted the morality of heathen philosophers like Seneca above the teachings of Christian preachers. It was, of course, not free from errors of its own. How could it be?

Both Albertus Magnus and Bacon, like all the men of their time, admitted astrology to a place among the sciences. Every one agreed that the stars influenced the destinies of individual men. Bacon went further and declared that the future of religious systems depended on conjunctions of the planets; that christianity would perish at a future conjunction of the moon with Jupiter! He believed in this insane folly with just the same sincerity as in his wonderfully intelligent and essentially correct theory of the rainbow; and he enforced it with like vigor.

The originality of Bacon's mind shocked the timid opinion of his time. The harshness of his character swept the earth free of friends. The errors of his astrology gave a handle to his enemies. In this matter they were more nearly right than he. Is it any wonder that he was disciplined and imprisoned by generals of the Franciscans, whom he had attacked; that the chapters of his order fully confirmed his sentences; that the popes approved them?

Was his fate the result of a warfare between religion and science? Let us consider the question closely. The doctrines of Bacon were condemned by the church, the true doctrines along with the false. Church dignitaries chose the Dominican friar, Albertus Magnus, as their representative rather than the Franciscan friar, Roger Bacon. We, to-day, after six centuries of struggle with ignorance, know that Bacon's system, as a whole, is wonderfully original, comprehensive, correct in method, fruitful in results. We entirely forget his errors; we are amazed at his profound intelligence. Great as Albertus was in his time, we, to-day, see that his contribution to the world's ideas is

small compared with that of his rival. How could the churchmen of the thirteenth century possibly know this? It has taken six centuries for us to learn it. Bacon's *Opus Majus* was first printed in its complete form in 1897—seven years ago, six centuries after his death.

His colleagues only knew that his brilliant and profound scientific ideas were too hard for them to follow. His theory of the rainbow, for instance, was not confirmed until the time of Descartes (1630). His correct theory of the Milky Way was not proved until 1610. His doctrine of 'species'—of the radiation of energies like gravitation—was not completed so as to be generally intelligible until the time of Huyghens, Hooke and Newton (1700). His conclusion that light is not propagated instantaneously, but takes time to pass from place to place, was not confirmed until the day of Roemer (1700). His guesses at the nature of heat could not have been understood or verified till the day of Count Rumford (1790). Bacon died in the year 1294.

How were his colleagues to judge of such profundities? They could not. But in looking through his scientific works they found that he held, with equal tenacity, a conclusion which they were entirely capable of judging. He declared that at a future conjunction of the moon and Jupiter the christian religion would perish. They believed their religion to be immortal. Bacon subjected a spiritual truth to material things; a divine institution to configurations and conjunctions of the planets. The first duty of institutions, states and individuals is self-preservation. For the church to accept Bacon's conclusions was sheer suicide. They were accordingly condemned. Along with the false the true suffered. It was an immense loss to the science of the middle ages and of the world that these things so fell out. But can it be wondered at? Were they, in any strict sense, the signs of a conflict between religion and science? The science that was especially condemned was false science; it was not true; it was, moreover, an attack on the very life of the church. Is not the whole episode just one step in the laborious, painful, slow, disheartening struggle between enlightenment and error—between illumination and ignorance? Must we not interpret the melancholy history of Jordano Bruno in the same way? Science had far less at stake in his case than in that of Bacon.

It may fairly be said, that up to the time of Galileo there never was, in any true sense, a conflict between religion and science. I am not here concerned to push the inquiry beyond this date of 1615. The controversies of the nineteenth century are, perhaps, of a different nature. During the earlier centuries there were endless warfares between one religion and another, between religion and heresy, between science and pseudo-science, but not between religion and science, as such. Looking backward, we now discover that the science of the nineteenth century would have been in conflict with the theology of the thirteenth. But in the thirteenth century itself, and

in every other century, the warfare was, in general, between religion and heresy—not science; between science and pseudo-science—not religion. The distinction is fundamental. It arises from the very constitution of man and the world he lives in.

From the time when primitive man first learned to light a fire until the present instant, there has been an increasing struggle between man and external nature; between man and the immaterial ignorances of his mind, also. Little by little, by slow steps, external and material nature has been subdued or circumvented in man's pursuit of comfort. Security and leisure, with their by-products, are the mile-stones along the tortuous path. Little by little the ignorances, anxieties and fears of man's spirit have been driven out, or, it may be, circumvented (one set of disquieting illusions sometimes being replaced by another) in his pursuit of spiritual happiness. Even material comfort has not yet been attained for society at large—witness the housing of the poor, and the death rate of young children—though we are far on the road towards it.

Veritable progress has been made on the road to spiritual happiness also. The spiritual welfare of a man is bound up in his beliefs—in his religion. To attack and unsettle the beliefs of any age is to threaten its happiness in a vital spot and such attacks are always vigorously repelled. A blow directed against ideals sincerely held hurts; and is resented. That they are ignorantly held does not lighten the blow. We have, to-day, partially—and only partially—learned the lesson that if we would not stagnate in error we must welcome criticism. We have learned that a patient tolerance of criticism is one condition of progress.

The veritable conflict of the past has been between enlightenment and ignorance; between true religion (the residue left after countless onslaughts of heresy) and false; between true science (again, a residue) and pretended. The issue has been along the road that we call progress—the residue of insight and acquirement left to us after the experience of the ages. We have at last learned that even our divagations from the straight path are not all in vain; that our teaching comes through our errors. Men of genius commit their errors but once; they become our leaders because they learn more quickly; our own errors are countless, are ceaselessly committed, and it may be, in time, corrected. All that we have acquired has come direct to us from such leaders; all that the mass of men have learned is to glean the fragments the leaders let fall, and to have a patient, or it may be frivolous, tolerance of novel ideas and of suggested change. Leaders who have escaped martyrdom of one sort or another we may account unusually fortunate, or exceptionally adroit.

Looking backwards, then, over the centuries we see perpetual conflict with ignorance, perpetual struggle in both the physical and the

spiritual worlds; and specifically a struggle in one world between true and false science, in another between religion and the heresy of the time. If we survey the whole of history at a glance we see that the science of one epoch has often been at variance with the religion of another; but we also see that in each and every age the conflict has been between things of one and the same kind; between religion and its opposite, between science and its opposite; and not in general between things so different in their nature as science and religion.

The histories of the so-called 'martyrs of Science' should be interpreted in the light of the foregoing conclusions. It may be that some readers, even while admitting the argument here set down, will leave it with an uneasy feeling that it can not, after all, be correct. It differs from received opinion. It is so much at variance with the views expounded in books of the warfare-of-science sort. But *is* it? As to opinion, I will quote a phrase of Kepler's:

> *The whole of philosophy is nothing but innovation, and a combat with immemorial ignorance.*

Kepler was in the thick of the fight and knew that of which he spoke. He blames ignorance and not religion, nor theology. As to the real teaching of the books in question, I will quote two paragraphs from President White's 'Warfare of Science with Theology in Christendom.'

> I. Nothing is more unjust than to cast especial blame for all this resistance to science upon the Roman Church. The Protestant Church, though rarely able to be so severe, has been more blameworthy.
>
> II. As to the older errors the whole civilized world was at fault, Protestant as well as Catholic. It was not the fault of Religion; it was the fault of that short-sighted linking of theological dogmas to scriptural texts, which in utter defiance of the words and works of the Blessed Founder of Christianity, narrow-minded, loud-voiced men are ever prone to substitute for Religion.

The first citation is amply proved in the book from which it is taken. The second lays the blame precisely where it belongs, namely, upon the whole civilized—that is, partly civilized—world. The conflict was the outcome of invincible ignorance; it was an episode in the progress towards enlightenment. It had nothing to do with religion—Dr. White so states. That it had nothing to do with theology will be clear when we reflect that the particular form of men's theology determined only the particular manner in which their ignorance was manifested. Catholics chose one form; Protestants another. The real cause underlaid theological form; and was the ignorance of 'narrow-minded' men. It was independent of 'scriptural texts,' though they were often quoted to serve a purpose. From Dr. White's own words it appears that the conflicts of science have not been, in general, with religion, nor yet with theology; but with the 'immemorial ignorance' of 'narrow-minded men,' recognized as the arch-enemy by Kepler, the protagonist, and recognizable all about us to-day, if we will but look.

THE GREAT WHITE PLAGUE.

By Dr. JOHN B. HUBER,
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IT is with a very real sense of melancholy that one contemplates the long death-roll of those of the world's great men and women who have succumbed untimely to the tubercle bacillus, which is and has been through countless generations by far the most potent of all death-dealing agencies. Had it not been for this detestable parasite, Bastien Le Page might have given us another Joan-of-Arc to feast our eyes upon; Rachel might for many years have continued to permeate the spirits of her audiences with the divine fire that was in her. Our navy did well enough in the 1812 war, as all the world knows; but what a rip-roaring time there would have been if John Paul Jones had lived to take a hand in it. We might be reading some more of Stephen Crane's splendid war stories; we might have had some more of Robert Louis Stevenson's delicious lace-work; Schiller might have given us another 'Song of the Bells'; we might have taken another 'Sentimental Journey' with Laurence Sterne; Henry Cuyler Bunner might have continued to delight us, and to touch our hearts; John Keats might have given us another Endymion. Had the tubercle bacillus permitted, Nevin might have vouchsafed us another 'Rosary'; von Weber another 'Euryanthe Overture'; Chopin might have dreamed another 'First Polonaise'; and the tender flute notes of Sidney Lanier might even now be heard. Maria Constantinova Bashkirtseff, Zavier Bichat, John Godman, Rene Theophile Hyacinth Laennac, Henry Purcell, John Sterling, Henry Timrod, Artemas Ward, Henry Kirk White, Henry David Thoreau, Baruch Spinoza—such names as these are but a moiety among those of the world's nobility, whose precious lives were cut off in their prime by the 'Great White Plague.'

And our sense of resentment is by no means mitigated when we reflect that this bacillus is so minute that it was reserved for Koch, in our own time, with the aid of an exquisitely high-powered microscope, to discover it, and to reveal its life history and its habits and properties. It were indeed worthy the pen of a Heine to set forth how, although our mastodons are extinct, although we easily destroy all other visible brute creation, although we hold ourselves to be world masters and universe compellers, the race has nevertheless until our generation been impotent in the presence of an organism, measuring in length one ten-thousandth of an inch and in breadth one fifty-thou-

sandth of an inch—an organism which multiplies so rapidly and so invisibly and insidiously that the consumptive, in coughing, emits several billions of it during twenty-four hours.

There would be no excuse truly for putting such sinister details as these before the laity were it not that the condition of things, which we term consumption or tuberculosis, is a tremendous, much-pervading human factor. I have intimated that of all death-dealing agencies, Koch's bacillus claims the greatest number of victims; the cholera, typhus, the plague of the middle ages, small-pox—are not in the running with consumption. The last, although its ravages have not been so picturesquely gruesome, has claimed many more victims than any of the others; it has probably been coeval with human existence, and very likely has afflicted our primordial ancestors.

To-day every third or fourth adult dies of consumption. In the periods between birth and senescence every seventh death is caused by it. The point about these two propositions is this: Very few of us die only of old age; almost every one dies of one disease or another, so that it would not seem to matter much what the particular disease might be that would carry us off. But, although all periods of life are precious—infancy and childhood and old age, as well as any other—it is during adult life that consumption gets in its fell work, in the periods when young people should entertain wholesome anticipations of matrimony, when husbands should be strong to work for and maintain their families, when wives should have strength to rear their children, and when men and women generally should have physical and mental capacity so that they may accomplish the world's work.

No one knows better than the physician how truly touching may be the condition of things we are considering at the first of these periods—the period of early manhood and womanhood, when poetry, music, flowers, sunshine, and the new-born instinct to love and power to inspire love, are gloriously dominant, when sentiments ring true, when thoughts of compromise with unworthy factors, of subordinating ideals to considerations of interest, have not yet been conceived; when the love exists which welcomes sacrifices and feels that if it is ever to manifest itself, it should do so most gladly and most abundantly when the beloved is sorely stricken; the love that feels bound to triumph over all obstacles, and which snaps its fingers contemptuously in the face of fate. One is proud for human nature when such spirit is exhibited. Nevertheless it is then that this dreadful disease demands with deplorable frequency to be reckoned with. And it is then that the mature physician discerns the practical certainty that marriage, in cases where consumption exists or is suspected, will be followed by intensified illness, and perhaps death (which might not otherwise have occurred), on the part of the sick one; the possibility of infection of

the healthy mate; the likelihood of unhealthy offspring, or of its early and perhaps—under the circumstances—fortunate death; and other indications suggesting disaster at the very beginning of married life, when all the circumstances, if any time in life ever required it, should be favorable and founded upon virility of mind and body.

The tubercle bacillus gets into the body either with the air we breathe, or with tuberculous food-stuffs, or rarely through wounds. Wherever it implants itself an inflammation may occur about it, with the result that a tubercle is formed (*tuber* is Latin for root or bulb). This tubercle is in size from that of a millet seed to a hickory nut or larger. Its development is called tuberculosis. Under favorable circumstances it becomes surrounded by fibrous tissue, somewhat like the scar which would follow a wound of the skin; and then the tubercle will be comparatively harmless to the organism. However, 'cheesy degeneration' may result, two or several adjacent tubercles may break down together, a cavity may form, containing purulent material in which, on being coughed up, the bacilli are discerned by the microscope. These bacilli and these tubercles may exist in any part of the body—the skin, the bones, the joints, the lymph glands. And they, or the products of their disintegration, may be carried by the lymph and blood channels to other parts; and it is probable that in many cases the pulmonary type of tuberculosis is not originally a lesion of the lung tissue, but a product transferred from a point of implantation elsewhere.

If tuberculosis does not undergo fibrosis it is likely to be developed, through the agency of some acute 'predisposing cause,' into the complex of symptoms which we term consumption. Those thus afflicted become progressively very weak and very much emaciated. Their hearts beat rapidly and they are apt to have a pink flush on their cheeks, which is quite unlike the blush of a healthy person, but which is in reality an indication of the fever that is consuming them. The rest of their faces is very pale and thin and is suffused with a clammy sweat. Their cheek bones are prominent. And their eyes have a quite unnatural brilliancy, seeming large and beautiful. But their luster is not of health—rather of disease and too often of death. It is such eyes that the poet Bryant has portrayed in a touching and melancholy sonnet. And the consumptive spits blood sometimes, and is short of breath, and has a persistent, hacking cough, that harasses him dreadfully, and does not let him rest.

The reader is now likely to wonder how, with all these teeming billions of bacilli about, any one ever escapes the disease. The fact is, the bacillus allows very few of us to die without leaving some trace of its activity in our system. *Jeder Mensch hat am Ende ein bischen Tuberculose,* as Naegali demonstrated in 98 per cent. of the bodies

which he examined on autopsy, of people who had died of all sorts of disease, besides those dying of old age.

There are two conditions essential to the development of consumption. In the first place, there must be the presence of the bacilli of Koch as its specific or essential cause. In the second place, the body must be predisposed to the disease by various unhealthful factors, such as vicious heredity, alcoholism, poverty and the like. Most of us are able to resist the bacillus because our bodies are sufficiently strong to resist the organism, and because there are in our tissues certain germicidal properties, which are ordinarily sufficient to cope with and destroy the bacillus. The layman will easily get the idea from the following experiment: Some rabbits were inoculated with tubercle bacilli and placed in relations generally deleterious to health; these became consumptive. Another group, selected from these same rabbits, were likewise confined, but were not subjected to infection, and these did not develop the disease. Whilst among a third group, which were inoculated like the first, but which were, on the contrary, favorably located as to hygiene, most of the rabbits escaped the disease.

The tubercle bacillus is indeed originally a saprophyte, feeding upon dead or decomposing material. Its next congenial habitat is such tissue of living animals as has been previously devitalized by unwholesome factors; that is to say, these factors have rendered the tissues of the body vulnerable to the onset of the bacillus and certain other microorganisms which later join it in its work of devastation. These predisposing factors render the tissues a fruitful soil in which the bacillus and its allies may germinate and thrive. I should like to touch briefly upon certain of these predispositions.

It was formerly held that consumption is a hereditary disease. But we know now it is practically impossible for such to be the case, for parents can not transmit the bacillus to their offspring. What parents *may* transmit is a tendency to the disease, resulting from unhealthful conditions in their own organisms. Such hereditary transmission may be manifested by the offspring in the scrofulous temperament. The child may have a pallid skin and flabby flesh; and inflammation of the mucous membranes, as would be indicated by reddened and suffused eyelids, coryza and congested and unhealthy throats. There would be adenoid growths in the back of the nose and enlarged tonsils, so that such children would be mouth breathers, starved for oxygen. The glands of the neck and in other parts of the body would become enlarged. Besides these things, there might be malformations of the thorax and a capacity for breathing evidently below the average, congenital affection of the heart and the rest of the circulatory system, slow teething and deficient and tardy ossification. There would, in short, be evidence of defective development and of a generally torpid condition of the system.

It is easily to be comprehended how tuberculosis can become engrafted upon such an organism. The French government has grappled most nobly with the problem indicated in this state of affairs. It has established in various parts of France hospitals for tuberculous children, many of whom are no doubt only scrofulous. Several of these institutions are on the sea coast, at Berck-sur-Mer and at Hendaye; and the children are assured the benefit of the sea air, and of ozone, lots of sunshine, plenty of pure food-stuffs—bread, meats, milk and eggs; careful nursing; and excellent medical care of their 'white swellings' of the joints, tuberculous affections of bones, and of the many other conditions requiring the physician's attention. Thus, instead of early deaths, or of the prospect of growing up weaklings, many of these children are vouchsafed happy lives and strong constitutions, thereafter resistant to infection, and have inculcated in them habits of cleanliness and hygiene which they are sure to disseminate after their graduation. In this manner there are secured to the state many worthy and splendid citizens who would otherwise be lost to it. It is really a movement worth the consideration of the political economist.

Excessive alcholism stands in a causative relation to tuberculosis because of the resulting tissue impoverishment. The pulmonary type is almost invariably found in persons dying in the course of chronic alcholism. *'L'alcoolisme fait le lit de la tuberculose,'* states the physician, Landouzy.

It is difficult to explain the effects of alcohol. Like most of the simplest things in life, no definite agreement has ever been reached concerning its mode of working. It is evident, for instance, that there is no hardier stock than the wine-drinking countries; and it would seem that alcoholic fluids that are of good quality and purity, and are taken temperately, are conducive generally to health.

In all likelihood the bad effects fairly attributable to alcohol lie largely in the vicious quality of what is consumed, and in the state of affairs which it connotes: unsanitary habits, poverty, lack of nutrition or bad food, ill-ventilated living rooms; and, most of all, a condition of the organism exhausted by overwork, in which the reserve force is all that is left to carry on the struggle for existence. We may imagine a man in whom the tidal strength, such as we use in dealing with the ordinary affairs of life, is gone, and who has to depend upon his reserve strength to cope with an extraordinary difficulty which would overwhelm him, but for which, if we had to deal with it, our reserve strength would be altogether adequate. Such a man is in the condition of the camel to whom the last straw is fatal. So alcohol is oftentimes taken first with a view to keeping a defective organism up to the working point, perhaps in a tuberculous subject, or in one in whom all the conditions are receptive to tuberculosis; alcohol is then taken in

increasing amounts to stimulate the flagging energies, thus making a bad matter worse. Some who contract the disease in this way have occupations directly conducive to alcoholism, such as workers in the liquor trade, barmen, waiters and hotel servants, people who are thus employed because they are, from their physical and moral make-up, 'unfit' (as the evolutionist might say) for another and a better sort of work.

Poverty, with all that the word implies—underfeeding, deficiency of sunlight, defective ventilation, overcrowding, uncleanliness, bad drainage, rank-smelling and damp-walled houses—stands enormously in a causative relation. There are plenty of data to demonstrate that tuberculosis is preeminently a disease of humanity's submerged strata.

It was estimated in Hamburg, for instance, among the several income tax classes (inclusive of the dependents of the tax-payers) that for incomes of from nine to twelve hundred Marks the death rate from consumption is 55.4; for incomes of from twenty-five to fifty thousand Marks the death rate is 7.5—a proportion against the poorer classes of nearly eight to one.

One may grasp the idea in a glance upon the maps of New York City districts which its Health Board has prepared under the medical directorship of Dr. Herman M. Biggs. By far the greatest number of our consumptives are in the poorer districts; eleven of them, for instance, dying in one year in a house in the 'lung block.' Instructive, too, are the thousand odd photographs which the New York City Tenement House Department has taken during the two years just passed, showing air shafts twelve inches wide and six stories deep; more than 360,000 'dark rooms' whose only means of ventilation, if they have any ventilation at all, is through such air shafts. Enlightening, too, is Mr. Ernest Poole's brochure on 'The Plague in its Stronghold.' Such grim humor as the following may also have illuminative value: Three families occupied an apartment of three rooms, one living in the front room, another in the rear room, the third in the middle room; and they all got along very well together until the family in the middle room wanted to take in boarders.

Besides these predispositions to tuberculosis there are many others. There are the family relations. If one member is consumptive, his sputum may in various ways be infective. It may be spat upon the floor, and if there is an infant, it will, in playing about, pick up bacillus-laden objects and, after the habit of infants, put them in its mouth. Then after weeks or months the child becomes tuberculous. So that on such accounts as these it was formerly considered that the disease itself was of hereditary origin. Then 'neglected colds,' fevers and exhausting diseases, such as typhoid or malaria, enervate the body and make it a fruitful soil for microbic germination. Direct injury,

or open wounds, or the shock occasioned by injury, or depressing emotions generally, may predispose. There are many trades which may stand in a causative relation to tuberculosis. In the excellent book entitled 'Dangerous Trades' there are nearly sixty such occupations specifically considered.

It were impossible even to mention all conditions which might predispose to consumption. For we are told that living itself is but the body's response to environmental stimuli, either physical or chemical in character; and such are about as numerous as there are external phenomena. For my part, I would reserve the opinion that the whole of life is by no means comprehended in this tenet; still it is valid as denoting the innumerable agencies, which may make the organism receptive to tubercular infection.

May we then hope to fight tuberculosis with any measure of success? Yes, indeed. To do so, two objects must be kept in view: We must destroy the bacillus; and we must render the organism of the individual resistant to infection. The disposition of the tubercle bacillus is theoretically extremely simple. Tuberculosis as an infectious disease is totally unlike certain others, as, for instance, diphtheria or scarlet fever. One can not be sure, after having been half an hour in the same room with a diphtheria patient, that he will not contract the disease. If, however, certain very elementary precautions are taken, one may live with a consumptive for months or years without jeopardizing his health. It has been truly said that there is no place where one is less likely to contract consumption than in a scientifically conducted sanitarium for consumptives. For instance, all the dust in one of Dr. Trudeau's cottages at Saranac Lake was gathered together, and a culture made from it; and this culture, when injected into a guinea pig, was not sufficient to give this little creature tuberculosis. And we may observe, in passing, that consumptives, who have been cured in such institutions, go out as well-trained medical missionaries, teaching others the habits of sanitation and cleanliness they have accustomed themselves to. Nor is any other community likely to be as healthy as one in which such a sanitarium is situated.

The sputum of the consumptive must be destroyed; and our government inspectors must see to it that no tuberculous meat and milk gets into our markets. These are practically the only sources of tubercular infection we need fear, and if these things were thoroughly attended to, there would be no danger of infection.

There are many, indeed, who have in this direction an unnecessary and not altogether dignified dread. For instance, some time ago a young woman left New York City for the west. She was of splendid intellectual capacity, amiable, gentlewomanly and withal of an exquisitely sensitive nature. She had little means; and, in order to

travel as cheaply as possible, she took a slow train, let us say, on a Monday evening. She reached her destination late on Wednesday afternoon, very much exhausted and very ill. Although almost six feet tall, she weighed, before going, just ninety-seven pounds. She had the lustrous eyes and the pink flush associated with consumption; her pale face was suffused with a cold, clammy sweat; and she had the cruel cough, which wracked her chest and would not let her rest. The first thing she did was to go to a home for young women, where she asked to stay over night, so that in the morning she could go to the sanitarium where her stay had been arranged for. They would not take her in. It was their rule to refuse consumptives, even for a night; and with the name of the 'Poor Nazarene' over their door, they turned her away.

The reader, if he have read only this paper, will now see that there was no occasion for this. We might dilate upon the spirit of Christliness, to which this institution would ostensibly lay claim, and through which spirit this very sick traveler might surely have been given shelter until the morning at least. But upon a purely practical basis, there is no reason why, with elementary knowledge and common sense, such as those controlling such an institution should have, this sick one could not have been provided for without in the least jeopardizing the health of any other person. The progress of civilization is never furthered, indeed it is most horribly retarded, whenever the stigma of inhumanity is fixed upon the fair countenance of religion.

THE DISCOVERY OF THE NATIVE HOME OF THE SAN JOSE SCALE IN EASTERN CHINA AND THE IMPORTATION OF ITS NATURAL ENEMY.

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THE insect which has had the greatest international importance and has been the subject of more interstate and foreign legislation than all the other insect enemies of plants together is a Chinese bark-louse of deciduous trees, known from its first point of colonization in America as the San Jose scale. This insect has been so thoroughly exploited in the publications, scientific and popular, in this country, and in horticultural and agricultural journals, that a general account of it is not necessary. It was first discovered in San Jose, Cal., in the grounds of Mr. James Lick, in the early seventies. It soon spread throughout California and the Pacific coast and became the most notable enemy of such fruits as the pear, apple, peach, prune and certain small fruits. Its name of *perniciosus* was given it by Professor Comstock, who studied it in California in 1880 and reported it to be the most destructive scale enemy of fruits known to him. It has more than maintained its reputation in this regard since that time.

Up to 1893 it was only known on the Pacific coast, but in that year it was discovered in a small orchard in Virginia, and the investigation which followed developed the fact that it had got into some large eastern nurseries a number of years before on plum trees from California, and had been spread from these nurseries unwittingly over much of the southern and eastern states. The damage which soon developed from this scale insect in the orchards of peach, pear and apple of the east aroused very considerable excitement, and the alarm thus caused was transmitted to foreign countries with the result that, beginning with Germany, one after another of the European powers adopted measures prohibiting the importation of American plants and fruits, or requiring rigid inspection before such admission. Canada adopted similar restrictions, and even such remote countries as the Cape of Good Hope, New Zealand and Java followed suit. Within the different states of the union also various prohibitions on traffic in nursery stock and plants were put in operation. Since 1893 this scale insect has steadily extended its range in the United States and also in Canada, where it soon gained foothold, and it now occurs in practically all the important fruit districts of North America. It has not

gained lodgment in Europe so far, and the chances are that if it should do so the climate of Europe is so unfavorable that it would not be nearly so mischievous there as in America.

The explorations, which are briefly narrated in this paper, were undertaken to discover the native home of this scale insect, which was, prior to 1901, a mere matter of conjecture. The desirability of discovering the origin of this scale pest arose from the now well-known fact that wherever an insect is native it is normally kept in check by some natural means, and as a rule by some predaceous or parasitic enemy. In the chance importation of foreign destructive insects to our shores it very often happens that the natural check or enemy is left behind, and the imported pest becomes in consequence much more injurious here than in its native place. In a number of notable instances in this country very great benefit has been derived by the discovery and introduction of such natural enemies, thus reproducing the conditions which obtain in the native home of the injurious insect. The fluted scale and the Australian ladybird in California is the most notable instance. The importation of this ladybird from Australia has made citrus growing possible in California, and saves annually many millions of dollars to that state. This and other similar cases indicated the desirability of discovering the native home of the San Jose scale, and the importation, if possible, of whatever natural means were found there keeping it in check.

Prior to this investigation there was a pretty well founded belief, shared by Dr. Howard and the writer, that the San Jose scale was a native of eastern Asia. Without going into detail, this belief was based chiefly on the ground that most other quarters of the world had been fairly well investigated without any evidence of this scale insect being found. It was known to occur in Japan, but the evidence rather indicated that it had been recently brought to that country from the United States in connection with the large shipments of nursery stock from California to Japan during the last twenty-five or thirty years. The itinerary, therefore, planned by the writer, with the advice of the chief entomologist of the Department of Agriculture, Dr. L. O. Howard, was to include Japan, China and any other countries in eastern Asia which it should prove desirable to visit. Six months were devoted to a very thorough exploration of the different islands of the Japanese empire, and three months to China, with shorter periods in other regions. The explorations in China and Japan are the only ones which bear especially on the San Jose scale problem.

Explorations in Japan.

During the time spent in Japan, from April to September, 1901, the writer visited some forty-two provinces, and explored all the prin-

cipal islands, representing a stretch in latitude the equivalent of from northern Maine to Florida. Altogether these explorations enabled him to make a pretty correct judgment on the San Jose scale problem in Japan. Japan is not especially a horticultural country. Her comparatively enormous population of 46,000,000 compels the growth of cereals and other necessities of life wherever possible. Very little land, therefore, is devoted to fruit raising, and fruits are considered as luxuries. Nevertheless, practically every dwelling house in Japan has a little dooryard or kitchen garden in which are single examples of cherry, plum, peach, persimmon and other trees. Furthermore, the roadways and temple grounds and streets are lined with cherry and plum trees, planted for bloom and ornament and not for fruit. There are orchard districts in Japan of limited extent. In northern and central Japan there are a few peach orchards and a few orchards of native pears, and in southern Japan, small orchards of orange, pomelo, walnut and other fruits. In old Japan the chief deciduous fruit is a native pear grown in small patches of from a fraction of an acre to two or three acres in extent. These are trained low on overhead trellises, and at a short distance look like vineyards. There are several districts where such orchards occur in considerable numbers. These orchards are very ancient, many of them having trees more than one hundred years old. If the San Jose scale were native to Japan it would occur in these pear orchards, the pear being one of the favorite food plants of this scale insect.

METHOD OF TRAINING OLD PEAR ORCHARDS IN JAPAN (height of trellis 5 feet).

In northern Japan, including the island of Hokkaido, and the northern end of the main island, Hondo, apple raising has been introduced in modern times very much on the lines of this country. Prior to the opening of Japan to foreign commerce and exploration, the apple as an edible fruit was unknown in that country. The orchards in northern Japan are chiefly, therefore, of American origin and rep-

resent American varieties. Most of the stock came from California, and much of it was undoubtedly infested with San Jose scale when it was received. There is, therefore, throughout these northern apple orchards, a mild infestation with this scale. The Japanese are very enthusiastic in their efforts to gain all the benefits of western civilization, and this is shown in horticultural as well as in other fields. The three leading nurseries, therefore, of Japan have been very active during the last twenty or thirty years in importing the different varieties of pear, peach and apple from America, and all three of these nursery districts have become infested with San Jose scale, evidently from such importations from California, where the scale has been widely distributed for thirty years. Outside these nurseries, however, in central and southern Japan, the San Jose scale did not occur, except where it had been introduced on new stock from the nurseries referred to. The old native pear orchards were free from scale, except where replants had been made of American varieties, or new native stock, to fill in breaks in the orchards. The infestation was very often just beginning and immediately surrounded the replants. In all Japan, therefore, in the little house gardens and temple grounds where were cherry, plum and other trees suitable for San Jose scale, this insect did not occur, except where the evidence was very plain of its recent introduction as indicated. Without going into details of the evidence, it is sufficient to say that the conditions in Japan are essentially the same as in this country. The San Jose scale is a recent comer. It was, in fact, not known in Japan prior to the year 1897, when its presence there was first determined, but it has now been scattered pretty widely by nursery stock, exactly as in this country, and occurs under similar conditions; in other words, only where it has been recently introduced. The investigation showed very distinctly that Japan could not be considered responsible for the San Jose scale.

Explorations in China.

Investigations up to this point, while freeing Japan from the onus of giving the San Jose scale to the world, left the problem unsettled as to the original home of this insect. China remained as the most likely place of origin, and the writer proceeded to China to continue his explorations there. While in Japan a good deal of information was gained relative to fruit conditions in China, from English, German and American residents who were spending the summer months in Japan to escape the rather trying climate of China. In brief, it may be stated that deciduous fruits are grown from the Shanghai region northward, the peach being practically the only fruit grown to any extent about Shanghai. The great apple district of

China is the region lying back of the city of Chifu in the north. This apple-growing industry was started many years ago by a missionary, Dr. Nevius, and has assumed very considerable proportions and covers a good deal of the province of Shantung. Below Shanghai, the orange and other subtropical fruits replace the deciduous varieties. North of Chifu native fruits only are grown, consisting of the native pear and peach, and such wild fruits as wild crab apples and an edible haw apple.

A very considerable exploration of the country lying immediately back of Shanghai was made in the course of a long house-boat trip. A

A NATIVE FRUIT STAND IN CHIFU, CHINA.

great many peach orchards were examined and a good deal of miscellaneous fruit and other plants growing about house yards were inspected. Nowhere was there any evidence of the San Jose scale, nor were scale insects of any sort much to be seen. The climate of this region is unfavorable for such insects and they are normally killed out by fungous disease. The writer afterwards proceeded by boat to Chifu—a five-day ocean trip from Shanghai, and made a considerable exploration throughout the apple orchards of this region on horseback, visiting, among others, the original orchards planted by Dr. Nevius. In all these the San Jose scale was found scatteringly present, not, however, doing any special damage, and probably not enough to be

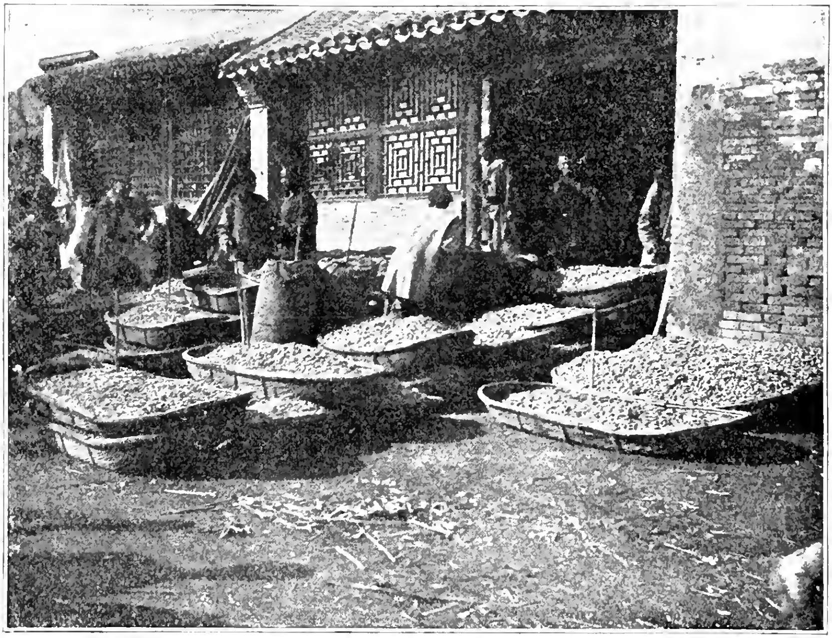
noticed, if its possibility for evil was not so well established. The presence of the San Jose scale in this region did not, however, have any special significance, since much of the original stock was obtained from California, and doubtless from nurseries which were infested with the scale.

The journey of exploration was continued northward to Tiensin and Pekin. In this region the San Jose scale was also found on native plants, including the flowering peach, a tree grown for ornament solely, and not for fruit, and notably on the native fruits in the markets in these cities.

PONY FRUIT CART IN WHICH PRODUCTS OF THE HILL COUNTRY ARE BROUGHT INTO PEKIN, CHINA.

The markets of Pekin were of especial interest in this connection. Pekin is the center and market for all the region lying to the north and west, and the streets devoted to the sale of fruits and other products in the Chinese city are one of the great show places. The fruit and nut products are brought into Pekin in little two-wheeled carts, or more generally on camelback, great caravans of heavily loaded camels and streams of carts constantly entering the city with the products of the outlying provinces. One finds, therefore, in the markets of the Chinese city the fruit products of all northern China, and can study them at ease. All the district lying between Pekin

and the great wall, north, and west, and east, has been most carefully explored and mapped by the foreign military authorities. From various individuals employed in this minute survey a great deal was learned relative to the fruit growing in the district indicated. Much of the fruit found in the markets of Pekin comes from the hill region leading up to the mountains separating China from Mongolia and Manchuria. These fruits are native apples, pears and peaches, and the little haw apple already mentioned. Great quantities of these fruits were examined in the market, with the exception of the peach, which



Portion of Wholesale Fruit and Nut Street in Pekin, China, showing Nut Products Chiefly Peanuts.

was then out of season, and later similar examinations were made at Tiensin. A very scanty but general infestation with San Jose scale was found on the different fruits examined. Perhaps one apple in a hundred would have a few of these scales about the blossom end and the same proportion was true of the haw apple and the native pear. Throughout the region where these fruits are grown, there has been no introduction of foreign stock. The occurrence of the San Jose scale on these two fruits was conclusive evidence that in the region whence it came the San Jose scale is native. The scattering occurrence of the scale also indicated, as would be anticipated, that this pest in its native home is kept in check by natural means.

The investigations made at Shanghai, and later southward to Hong-

kong, the Malay Peninsula and Java, indicated that the San Jose scale in eastern Asia can not survive below Shanghai.

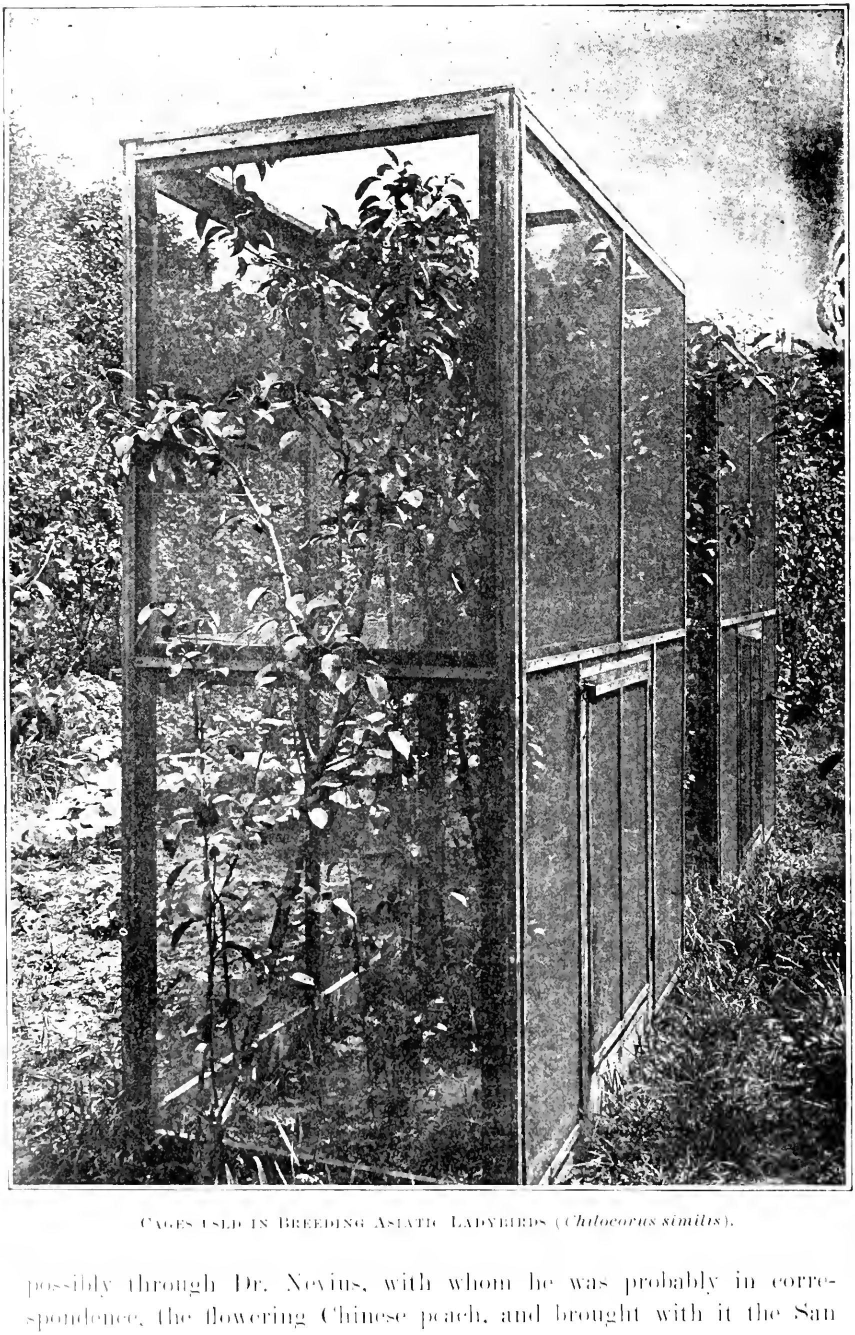
The special district where it is native and thrives is a fairly well shut off region, which probably accounts for the failure of this insect to become a world pest ages ago. This district is the region leading up to the mountains and comprising the northern and northeastern frontiers of China proper. Beyond the great wall on the north and west lies Mongolia, consisting chiefly of the vast Desert of Gobi. To the northeast and separating the region from Manchuria and Corea is

PORTION OF STREET DEVOTED TO SALE OF FRUITS IN PEKIN, CHINA.
[In foreground, fruit samples; in background, storehouses, also dromedaries employed to bring products from remote provinces.]

the eastern Gobi desert. To the south and east lies the great alluvial plain, the product of centuries of mud carried down by the Yellow River, a region where cereals only are grown. These are all effective barriers, and especially so when considered in connection with the political conditions of the past. We have, therefore, as the original home of this insect a naturally shut-off area from which it could not easily escape under the conditions prevailing up to our own times.

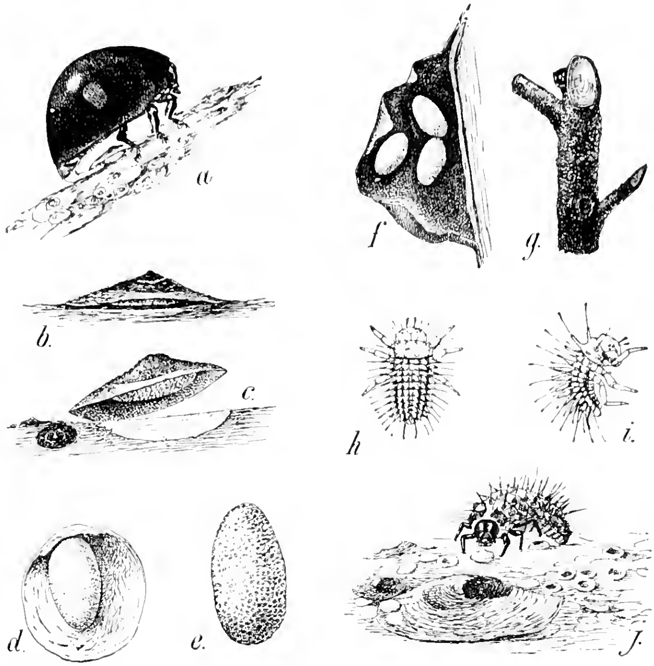
The means by which the San Jose scale came from China to America is a matter of interest. This pest reached California on trees imported by the late James Lick, a gentleman who was an enthusiastic

horticulturist and an energetic importer of plants from foreign countries. It is the writer's belief that Mr. Lick imported from China,

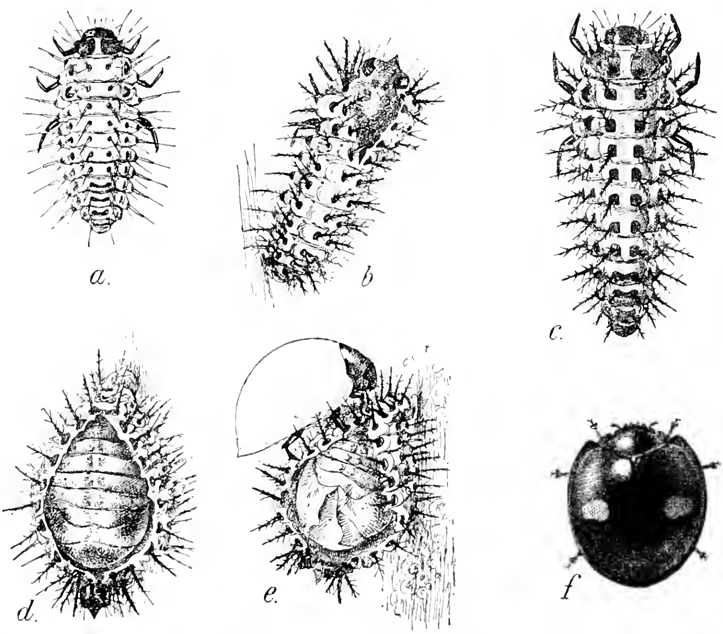


CAGES USED IN BREEDING ASIATIC LADYBIRDS (*Chilocorus similis*).

possibly through Dr. Nevius, with whom he was probably in correspondence, the flowering Chinese peach, and brought with it the San



Asiatic Ladybird (*Chilocorus similis*), oviposition and early larval stages: *a*, beetle in act of thrusting egg beneath scale; *b*, scale slightly raised, showing edge of egg beneath; *c*, scale lifted from bark, showing manner of attachment of egg to the inner surface; *d*, view of egg in the scale; *e*, egg magnified to show sculpturing; *f*, three eggs placed under flap of bark; *g*, same, natural size; *h*, *i*, dorsal and lateral views of newly hatched larva; *j*, larva, first stage, feeding on mature and young scales—all enlarged except *g*.



Asiatic Ladybird (*Chilocorus similis*), later larval stages, pupa, and adult insect: *a*, second larval stage; *b*, cast skin of same; *c*, full-grown larva; *d*, method of pupation, the pupa being retained in split larval skin; *e*, newly emerged adult not yet colored; *f*, fully colored and perfect adult—all enlarged to the same scale.

Jose scale to his premises. Undoubtedly this scale insect came to this country in some such way on ornamental stock from North China.

The Asiatic Ladybird, the Natural Enemy of the San Jose Scale.

Throughout the region investigated in China where the San Jose scale occurs the natural agency keeping the scale in check was evidently a small ladybird (*Chilocorus similis*), which was feeding voraciously upon it wherever the scale was found in any numbers. A considerable quantity of these beetles was collected in both Japan and China and sent by mail to Washington. Unfortunately, most of the specimens died in transit or during the first winter. Two individuals, however, survived, and during the first summer from these two some five thousand or more beetles were secured. The original stock was kept in cages, but later on the insects were liberated in an experimental orchard attached to the insectary of the department. During the first summer a considerable number of colonies were sent out to various states placing them in charge, in the main, of the entomologists connected with the state experiment stations. During the summer of 1903, the second one since the introduction of this insect, some thirty or forty additional colonies were distributed. A good many of these colonies were liberated under rather unfavorable conditions, and the beetles probably perished. The best success has come from certain colonies sent to Georgia. One of these, located at Marshallville, presents a most satisfactory outcome. This orchard contains some 17,000 peach trees, covering about 85 acres, and has lying immediately adjoining it a much larger orchard belonging to the same owner, containing 250,000 trees, all scatteringly infested with scale. The ladybirds were liberated in August, 1902, in the smaller orchard. An examination of this orchard in July, 1903, indicated that the beetles were rapidly spreading and that they would soon cover the smaller orchard. A rough estimate at this time of the number of ladybirds in all stages places the total at somewhere between 25,000 and 40,000. In Georgia the beetles evidently continued breeding up to January. There is, therefore, in this orchard at least, a very flattering outlook for good results from the imported beetle. Other colonies placed where there were only two or three or but a few trees have not yielded very satisfactory results. This outcome is not especially surprising, as under such circumstances the beetles are very apt to fly away and become lost. We are endeavoring, therefore, to place colonies where there are rather large bodies of trees infested with scales. After the beetle becomes once well established, distribution can be more general, but until this end is reached it is probably wiser not to waste material in sending specimens for colonization to small orchards or gardens or for liberation on a few trees. In Japan and China where the *Chilocorus* occurs rather generally, it finds food for itself in every dooryard, the white

peach scale being very widely distributed in those countries and the San Jose scale also in northern China and portions of Japan. In this country, on the other hand, the San Jose scale is practically its only host insect, and in spite of the wide dissemination of the San Jose scale, it still occurs after all in a very scattering way in orchards here and there, with often twenty or thirty miles between places of infestation. This imported insect can not, therefore, multiply and extend itself as rapidly and naturally as would be the case if the San Jose scale occurred more generally. For this reason it will be necessary to distribute the imported beetle artificially for some time. In Georgia, Alabama and other regions where there are general orchard districts it will undoubtedly be able to take hold much better than it will in regions where orchards are more scattering and of smaller area. Ultimately it is hoped that it will become established in America and have the same beneficial action which it now has in China and Japan. It probably will not be a complete remedy for the San Jose scale for the reasons already indicated, but if it will keep the San Jose scale in check as much as it does in its native country it will be of very decided service. One of its chief advantages will be the fact that it ultimately will take hold of the scale in many small orchards and gardens, the owners of which would be indifferent and would not undertake remedial operations, and thus furnish centers for additional reinfestation.

The importation of this insect can not work anything but good. It feeds only on scale insects, and ultimately may feed on certain of our native species as well as on the San Jose scale. It is a most voracious feeder, and has been observed to eat as many as five or six scale insects a minute, and even an average of but one a minute would give a total of 1,440 scale insects destroyed per day. The appetite of the larva seems never to be satisfied, and it is eating practically all the time. The adults also feed actively on the scale.

The chief drawback to this importation is the fact that several of our native predaceous insects have at once acquired a rather decided liking for the larvæ of the *Chilocorus.* A parasitic insect of our native ladybirds has also been attacking it in considerable numbers. These predaceous and parasitic insects may be sufficient to prevent this imported ladybird from giving the benefits which it ought. They have been especially in evidence in the Washington colony, but do not seem to have done any considerable damage in the more southern colonies referred to, and it may be that the ladybird will not suffer materially from them.

SAVING THE MISSISSIPPI'S SOURCE.

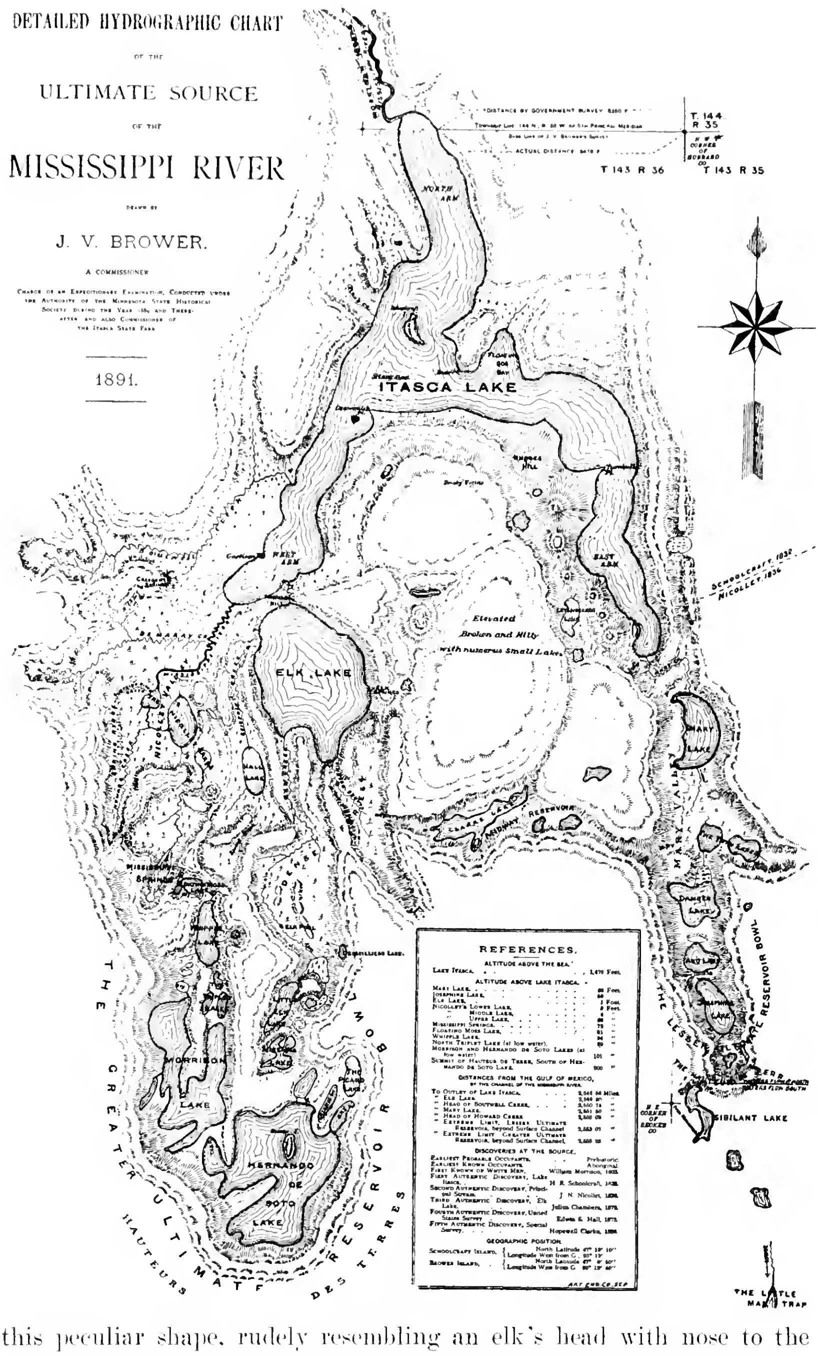
By H. M. KINGERY,

WABASH COLLEGE.

THE true American takes an honest pride in recounting the natural features of our country—its mountains, plains, lakes, rivers, cataracts, trees—all, in Yankee parlance, 'the greatest things on earth.' Of them all none is more truly worthy of admiration than the great river which practically spans our territory from north to south, draining an inland empire on its way. My vacation trip last summer took me to its source, and it is of this, with the peril that has threatened it and the measures taken to avert the peril, that I wish to tell briefly in this article.

We need not enter upon the vexed question as to what and where the real source is. Every explorer has found some new lake or river or spring which by ingenious definition he could make out to be the 'original and only' beginning of the Mississippi. Schoolcraft and the schoolboy agree in saying it is Lake Itasca; but there are streams entering that lake which if followed to their source would increase by a mile or two the total length of the 'Father of Waters,' and so satisfy more fully our national taste for bigness. The largest of these affluents is the 'Infant Mississippi,' discovered and named in 1836 by Jean Nicollet; but claims are made also for Mary river and lake, for Elk Lake and its tiny outlet, for the Mississippi springs, and for Hernando de Soto Lake. The truth is that each of these contributes its quota to the making of the Mississippi, while Itasca is the reservoir in which all their contributions are assembled. To the geographer it is a most interesting region, close to the watershed whence flow streams of widely different destination. The cook of a surveyors' camp located on this watershed used to boast that he could throw his dishwater to the left and send it to the Arctic Ocean, or to the right and start it towards the Gulf of Mexico. Not far away rise other streams whose waters find their way to Lake Superior and so to the Gulf of St. Lawrence. This peculiar configuration was known to the early French explorers, who gave the group of low hills the expressive title 'Hauteurs des Terres.'

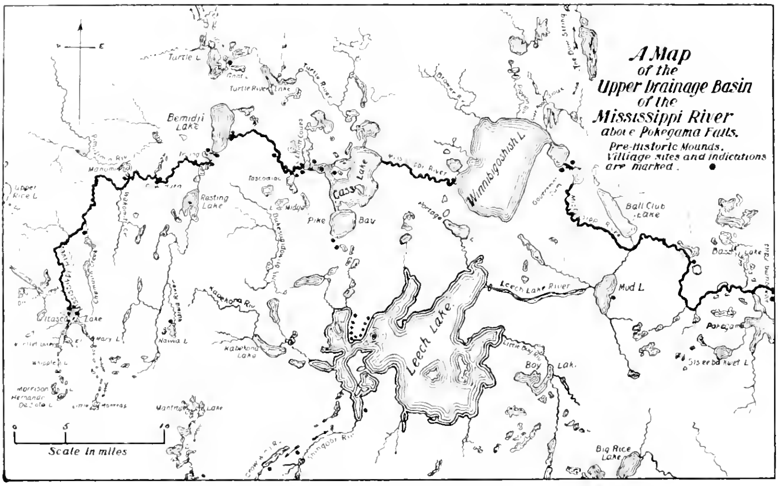
Lake Itasca lies in a valley of irregular horseshoe shape, encircled by a range of low hills, and is the largest of a considerable number of lakes in the same depression. Its form is most peculiar (as may be seen by a reference to the accompanying map); and it was doubtless



this peculiar shape, rudely resembling an elk's head with nose to the north and horns branching out towards the south, that suggested to the Indians the name they gave it—Elk Lake, translated by the French

into Lac la Biche. The present name is said to have been the joint production of Schoolcraft and the Rev. Dr. Boutwell, who were the first white men to seek this lake as the Mississippi's source. Desiring to hail it at first sight with an appropriate title, Schoolcraft asked his companion for the Greek or Latin words meaning the true source of a river. Though somewhat rusty in his classics, the reverend explorer finally recalled the two Latin words *veritas caput*—truth head. These

PLATE IV.



MAP OF THE MISSISSIPPI BASIN ABOVE POKEGAMA FALLS.

were written down, the first and last syllables crossed out, and presto! the name Itasca. The former designation, Elk Lake, is now applied to the largest of the tributary lakes.

The single island in Itasca is called Schoolcraft, in honor of the pioneer explorer, who spent a few hours upon it in 1832. The Mississippi, a tiny stream ten to fifteen feet in width and one or two in depth, issues from the north end of the lake, and, though its general course to the Gulf is east of south, its direction at first is west of north! By a curious coincidence a tributary of the Red River of the North, rising but fifteen miles west of Itasca, also begins its long race to the sea by taking a direction diametrically opposite to the true one—flowing south instead of north!

The peril mentioned in my first paragraph assailed the forests about the headwaters. The fine stand of white and Norway pines that once covered that part of Minnesota is fast disappearing, and the great lumber companies are on the lookout for every acre that can be made to yield its growth of centuries for their enrichment. For convenience of transportation the lumbermen have followed in the main the natural waterways, floating their logs down-stream to some suitable point for

assembling and shipping by rail. They have worked their way gradually up the Mississippi until in 1901 they were within a dozen miles (direct) of its source, ready at the first opportunity to attack that.

As to the effect of such an invasion one who has made a special study of the subject says: "As soon as the timber shall have been cut . . . the whole tract will become a burned, black and denuded waste, the streams and lakes will dry up and partially disappear and the reservoir dam necessary to drive the logs through and out of Itasca and Elk Lakes into the Mississippi River will drown out every tree and shrub standing upon the shores of said lakes." Another writes: "The reservoir system on the upper Mississippi has already seriously injured and in some cases destroyed the beauty of some of the finest combinations of lake and forest on the continent. It is to be feared that ere long the greed of speculators and the avarice of the lumbermen will finish the work of desecration and desolation." To the truth of these views the bare hillsides along the streams of northern Minnesota and the broad belt of dead, gray timber that encircles the great reservoir of Lake Winnibigoshish—a sort of forest cemetery—bear dumb but eloquent witness.

About 1890 the progress of this work of destruction began to alarm some of the thoughtful men of the state, and through their efforts the legislature in 1891 was induced to pass an act establishing and creating the 'Itasca State Park,' a reservation five by seven miles in extent and including the whole Itasca basin. Much of the land within this area had become private property by homesteading or otherwise, and some was included also in the government grant to the Northern Pacific Railroad. By purchase or condemnation the state soon secured control of the larger part, and since then appropriations have been made from time to time for the completion of such ownership. Some of the land still belongs to private owners and is not yet safe from saw and axe; but the good work is going on, and it is confidently hoped that very soon the last obstacle to the complete success of the plan will disappear.

In the management of the state park it is proposed to follow in general the policy adopted by the national government in regard to the Yellowstone region. Strict laws have been enacted for the protection of trees and game within its limits. Fishing is permitted (rod in hand), but hunting is absolutely prohibited. It is hoped that in time bear, deer and other large animals will come to recognize this reservation, like the Yellowstone Park, as a place of refuge, and that thus some rare species may be saved from extinction. For the enforcement of the laws a commissioner is resident on the grounds, vested with police powers. He is domiciled in a neat and comfortable cottage, built by the state and commonly known as the 'State House.' Our party, by the way, found in the clean beds and excellent fare of

the 'State House' a pleasant relief from the more or less crude comforts of camp life. The charges, too, were extremely reasonable.

With the restriction upon hunting already mentioned, visitors are free and welcome to use the park as their own; and, barring the discomfort of the long, rough ride from Park Rapids, and the size, activity and voracity of the mosquitoes that swarm there in summer, it would not be easy to find a more delightful and satisfying place for an outing. The beauties of woodland, lake and stream, the pure air that blows always in the pine forests, the opportunities for boating, fishing and exploring, and above all its absolute retirement and out-of-the-worldness, commend it alike to sportsman and the mere seeker for change and rest. Of the natural attraction of the valley one has written: "The multitude of clear little gems of lakes, embowered in picturesque hills, Lake Itasca itself a most lovely sheet of water, and especially the grand stretch of virgin forest, mark the park as a chosen corner of Nature's great garden." No less enthusiastic was Schoolcraft, who exclaims: "On reaching the summit our wish was gratified. At a depression of perhaps one hundred feet below, cradled among the hills, the lake spread out its elongated volume, presenting a scene of no common picturesqueness. . . . (It is) one of the most tranquil and pure sheets of water it is possible to conceive." Having had his first view of Itasca from almost the same spot the present writer can testify that the description is not overdrawn. Amid such scenes, with cold springs and grassy, well shaded campgrounds galore, and an abundance of fallen wood for fuel, one is in a veritable campers' paradise.

Utility and sentiment alike endorse the efforts made and making to save this valley from the lumber vandal. While many have lent their aid, the success thus far attained is due in large measure to the efforts of Hon. J. V. Brower, of St. Paul, who has not spared speech nor pen, time nor personal means in his endeavor to arouse the people and their representatives to a sense of what the loss of it would mean. His book on the source of the Mississippi and his large-scale map of the park, showing every detail most accurately, are recognized as authorities on the subject. His study of prehistoric remains on the upper Mississippi is by no means the least interesting part of his work.

The idea certainly is worthy of the great state which is carrying it out and of the sympathy and support of all who take pride in the natural wonders and beauties of our country. New York has made Niagara free; Minnesota is defending the Itasca basin from disfigurement and spoliation.

SOME EIGHTEENTH CENTURY EVOLUTIONISTS. II.

BY PROFESSOR ARTHUR O. LOVEJOY,

WASHINGTON UNIVERSITY.

II. *Diderot.*—Diderot was in even less degree than Maupertuis a contributor to the details of scientific knowledge; and the contrast between the work of the interpreter and that of the investigator of the facts of science is well shown in the relation of his theories to the discoveries of Daubenton. It was the great associate of Buffon who laid the foundations of the science of comparative anatomy, which was to furnish the most important arguments in favor of the theory of evolution; a French writer (Vicq d'Azyr) has even gone so far as to say that 'to the merit of having made a beginning of that science Daubenton has added the merit of having carried it through to completion.' After the publication of the third and fourth volumes of the 'Histoire Naturelle,' an important body of facts and comparisons relating to the anatomy of the vertebrates was accessible to all readers; it is one of the most serious blots upon the reputation of Buffon as a man of science that he failed to appreciate the value of this body of detailed knowledge, and in a subsequent edition of the work cut out Daubenton's anatomical contributions—to the great grief and disappointment of their author. Now the publication of the main facts of comparative anatomy brought clearly to light the striking homologies that run through the structure of all the vertebrate species. Daubenton himself, however, was not the man to see that these homologies suggested, and went far to justify, the hypothesis of the descent of all such species by progressive variation from a common ancestral prototype. His talent was not for the making of hypotheses, but for the collation of facts; he was a cautious and conservative man, capable of infinitely patient and accurate observation, but apparently not capable of penetrating to the significance of the facts which he observed. Even when the evolutionary hypothesis had been put forward by others, he gave it no encouragement; and it was apparently with the purpose of combating it that he contributed a paper to the French Academy of Sciences in 1764, arguing that the anatomical differences between man and the orang-outang are radical, and that man's general structure is elaborately adapted to the maintenance of the erect attitude, as the structure of the ape is not ('Memoires de l'Académie des Sciences,' 1764, p. 568). Similarly he argued, in his introduction to the natural-history volume of the 'Encyclopédie Méthodique' (1783), that man differs so essentially

from the animals, even in his anatomical character, that he ought not to be classed with them; and he expressed surprise that 'it has been possible for a celebrated naturalist to place man in the rank of the quadrupeds, and to associate him in the same class with the monkeys, the lemurs and the bats.'

Minds of another type, however, at once saw how the facts laid bare by Daubenton demanded for their satisfactory explanation a hypothesis such as Maupertuis had already come upon from another line of inquiry. Even Buffon, as is well known, pointed out, in the 'Histoire de l'Âne' in the fourth volume of the 'Histoire Naturelle,' how forcibly the homologies to which his colleague had called attention suggested the idea of a family relationship between all animals. "If," he wrote, "in the immense variety of animate creatures that people the world, we choose as a starting point for our study some one animal, or even the body of man, and if we compare it with all the other organisms, we shall find that . . . there exists a certain primitive and general type (*dessein*) which can be traced out very far. . . . Even in the parts which contribute most to give variety to the external form of animals, there is a prodigious degree of resemblance, which inevitably brings to our minds the idea of an original model upon which every creature seems to have been conceived. . . . As M. Daubenton has remarked, the foot of a horse, in appearance so different from the hand of man, is nevertheless composed of the same bones, and we have at the extremities of our fingers the same small bone of horse-shoe shape which terminates the foot of that animal." By one who considered these facts alone, "not only the ass and the horse, but also man, the ape, the quadrupeds and all the animals might be regarded as constituting but a single family. If it were admitted that the ass were of the family of the horse, and differs from the horse only because it has degenerated, one could equally well say that the ape is of the family of man, that it is a degenerate man, that man and ape have a common origin; that, in fact, all the families among the plants as well as among the animals, come from a single stock; and that all animals are descended from a single animal which in the course of time, as the result of progress or of degeneration, has given rise to all the races of other animals. . . . If it were true that the ass is a degenerated variety of the horse, there would be no longer any limits to the power of Nature, and one would not be wrong in supposing that from a single being she has been able to derive all the other organized beings." But of course Buffon finally pronounced, at least nominally, against such a supposition: *Mais non; il est certain par la révélation que tous les animaux ont également participé à la grace de la création.* Diderot, however—although he was himself not wholly unpractised in perfunctory and ironical professions of orthodoxy—was somewhat more

outspoken; and in his 'Pensées de l'Interprétation de la Nature' he declared plainly that the doctrine of the mutability of species and of their descent from a common prototype was, if not an established truth, at any rate a legitimate and a necessary working hypothesis for all future biological investigation.

The most interesting and most explicit passage on the subject in the 'Pensées' has, so far as I know, been noted by no English writer;* and I therefore translate it without abridgment. "It seems," says Diderot, "that nature has taken pleasure in varying the same mechanism in a thousand different ways. She never abandons any class of her creations before she has multiplied the individuals of it in as many different forms as possible. When one looks out upon the animal kingdom and notes how, among the quadrupeds, all have functions and parts—especially the internal parts—entirely similar to those of another quadruped, would not any one readily believe (*ne croirait-on pas volontiers*) that there was never but one original animal, prototype of all animals, of which Nature has merely lengthened or shortened, transformed, multiplied or obliterated, certain organs? Imagine the fingers of the hand united and the substance of the nails so abundant that, spreading out and swelling, it envelops the whole—and in place of the human hand you have the foot of a horse. When one sees how the successive metamorphoses of the envelope of the prototype—whatever it may have been—proceed by insensible degrees through one kingdom of Nature after another, and people the confines of the two kingdoms (if it is permissible to speak of confines where there is no real division)—and people, I say, the confines of the two kingdoms with beings of an uncertain and ambiguous character, stripped in large part of the forms, qualities and functions of the one and invested with the forms, qualities and functions of the other—who then would not feel himself impelled to the belief that there has been but a single first being, prototype of all beings? But whether this philosophic conjecture be admitted as true with Doctor Baumann [Maupertuis], or rejected as false with M. de Buffon, it can not be denied that we must needs embrace it (*on ne niera pas qu il faille l'embrasser*) as a hypothesis essential to the progress of experimental science, to that of a rational philosophy, to the discovery and to the explanation of the phenomena of organic life" (*op. cit.*, XII.). If the rest of the passage left any uncertainty as to the precise nature of the hypothesis that Diderot had in mind, the reference to Maupertuis and Buffon would make his meaning unmistakable.

* Osborn cites only another and less explicit passage from Diderot; and Mr. John Morley ('Diderot and the Encyclopædists'), although he notes a hint of the idea of natural selection in the 'Lettre sur les Aveugles' (1749), says nothing about the marked evolutionism of the 'Pensées de l'Interprétation de la Nature.'

In a later section of the book, in which he recurs to the subject, the mocking tone of Diderot's professed submission to the 'teachings of the faith,' only makes the more manifest the real opinion that he holds and desires to get accepted. "May it not be that, just as an individual organism in the animal or vegetable kingdom comes into being, grows, reaches maturity, perishes and disappears from view, so whole species may pass through similar stages? If the faith had not taught us that the animals came from the hands of the Creator just such as they are now, and if it were permissible to have the least uncertainty about their beginning and their end, might not the philosopher, left to his own conjectures, suspect that the animal world (*l'animalité*) has from eternity had its separate elements confusedly scattered through the mass of matter; that it finally came about that these elements united —simply because it was possible for them to unite; that the embryo thus formed has passed through an infinite number of successive organizations and developments; that it has acquired in turn movement, sensation, ideas, thought, reflection, conscience, sentiments, passions,—signs, gestures, sounds, articulate speech, language—laws, sciences and arts; that millions of years have elapsed between each of these developments; that there are perhaps still new developments to take place which are as yet unknown to us; that there has been or is to be a stationary condition of things; that the being thus developed is passing out of, or will pass out of, that condition by a continual process of decline, in which his faculties will gradually leave him just as they originally came to him; and that he will finally disappear from nature forever, or rather, will continue to exist, but in a form and with faculties wholly unlike those which characterize him in this moment of time?—But religion spares us many wanderings and much labor." Here, of course, we have not only the transformation of species, but also the sketch of a complete system of materialistic and ateleological evolutional philosophy, after the Spencerian fashion. Most of the chapters of Mr. Spencer's elaborate biography of the universe Diderot gives us in outline:—its 'integration of a diffused, incoherent matter,' its 'successive phases of physical, psychical and social development,' its 'equilibration' and resultant 'stationary state,' and finally its 'alternate cycles of evolution and dissolution.'

The passage first quoted, however, seems to me the more interesting of the two, not only because it is more outspoken and free from the veil of ironical piety, but also because it shows clearly the sources and grounds of Diderot's belief in the mutability of species. He had been stimulated to write largely by the recent appearance of the 'Systéme da la Nature' of Maupertuis; but he ignored the embryological line of argument, and rested his conclusion upon the homologies lately made known by Daubenton and dilated upon by Buffon.

Thus the decade between 1745 and 1755 was marked by the appearance of the attack of Maupertuis upon the ruling doctrine of predelineation; by the publication of the volumes of the 'Histoire Naturelle' which familiarized even the general reader with the unity of type and the homologies of structure that ran through the most diverse species in the writings of the three most celebrated French leaders of scientific opinion of the time; and by the setting forth of two distinct lines of argument in favor of that hypothesis. From this decade, then, dates the appearance of modern evolutionism, as a theory definitely formulated and based upon its proper embryological and anatomical premises.

III. *Herder.*—If certain of the French *philosophes* have received less credit than is their due for their evolutionary opinions, Herder, on the contrary, has often been praised for an early profession of faith in the doctrine of the transformation of species, whereas it is by no means clear that he did not intend explicitly to repudiate it. A German writer, Bärenbach,* has written a book to show that Herder was a precursor of Darwin, and declares that in his 'Ideen zur Geschichte der Menschheit' Herder laid down 'the fundamental laws of the modern development theory, and of the Darwinian theory in particular,' and that he gave clear expression to 'The law of the evolution of organisms, and the theories of the struggle for existence and of natural selection.' Professor Osborn's account of Herder's relation to the theory apparently follows Bärenbach, and as a result is rather misleading. Herder, says Osborn, probably was helped to his evolutionism by 'coming under the influence of Kant's earlier views.' But "Herder was less cautious than his master, and appears almost as a literal prophet of the modern natural philosophy. In a general way he upholds the doctrine of the transformation of the lower and higher forms of life, of a continuous transformation from lower to higher types and of the law of perfectibility." "In his 'Ideen,' published in Tübingen in 1806, . . . we see that Herder clearly formulated the doctrine of unity of type which prevailed among all the evolutionists of the period immediately following."

These few sentences contain a rather undue proportion of errors, and the whole exposition of Herder's position from which they are taken is substantially wrong. It is worth while, therefore, to attempt a more accurate account of Herder's attitude towards evolutionism than is to be found in the current writings on the subject. In a matter of this kind, even accuracy about dates is not wholly to be disdained; and it should be observed that the 'Ideen' were published, not at Tübingen in 1806, but at Riga and Leipzig in 1784–5. Again, Herder, although once a pupil, was no disciple of Kant's; the author of the

* Herder als Vorgänger Darwin's; *cf.* the same writer's monograph on Herder in 'Der neue Plutarch, VI.' My citation is from the latter work; the former is not accessible to me.

'Metakritik' would assuredly have been surprised to hear Kant called his 'master'; and it is sufficiently clear, from Herder's own language, that the influence which led him to employ such expressions as have caused some to consider him an evolutionist, was that of Buffon and other naturalists of the century, not that of Kant. During Herder's student days (1762–4) in Koenigsberg, indeed, it is improbable that Kant's influence could have encouraged a belief in organic, as distinguished from cosmic, evolution. On the other hand, it is not true that Herder was 'less cautious' than Kant in his treatment of the doctrine of transformation; for, by the time of the 'Kritik of Judgment' (1790), Kant had grasped the theory of the descent of species in all its implications and was ready to recognize it as at least a promising hypothesis; while Herder, in the 'Ideen,' argues at length against what he calls 'the improved and totally self-contradictory paradox' that animal species can depart from their divinely-defined character and that man is directly related to the ape.

Yet Herder's book is certainly full of *aperçus* that come near to the evolution theory; and it unquestionably helped to produce a state of mind favorable to the acceptance of the theory. Some passages in the 'Ideen,' read by themselves, might easily seem to justify the classification of Herder with the thorough-going evolutionists. For his position is peculiar and somewhat equivocal. Where he stands in the matter may perhaps best be shown by setting down in catalogue fashion the several contentions that he advanced in regard to the history of the animal kingdom and the relation of the lower species to man.

1. Herder clearly recognized that there had been a sequence of temporally successive forms appearing upon the globe, beginning with simpler forms and proceeding to those most highly organized; 'from stones to crystals, from crystals to metals, from these to plants, from plants to animals and from animals to man, we see the form of organization ascend; and with it the powers and propensities of the creature become more various, until finally they all, so far as possible, unite in the form of man (Bk. V., ch. 1). Each new type as it appears is dependent for its survival upon the prior existence of simpler types—dependent usually, indeed, in a very plain sense, since the newcomer commonly has the earlier-born creatures for its necessary food. "It is manifestly contrary to Nature that she should bring all creatures into existence at the same time. The structure of the earth and the inner constitution of the creatures themselves make this impossible. Elephants and worms, lions and infusoria, do not appear in equal numbers, nor could they be created, in consistency with their natures, at one time or in equal proportions. Millions of shellfish must needs have perished before our bare rock of earth could be made a fruitful soil for a finer type of life; a world of plants is destroyed each year in

order that higher beings may be nourished thereby. Even if one wholly disregards the final causes of the creation, yet even in the very raw material of Nature there lies the necessity that one being should come out of many, that in the revolving cycle of creation countless multitudes should be destroyed so that through this destruction a nobler but less numerous race might come into being" (Bk. X., ch. 2). "Man, therefore, if he was to possess the earth and be lord of the creation, must find his kingdom and his dwelling-place made ready; necessarily therefore, he must have appeared later and in smaller numbers than those over whom he was to rule" (*ibid.*). Most of this Herder might have got from Buffon; and there is obviously nothing in these passages which necessarily implies the mutability of species, nothing which is inconsistent with the doctrine of special but gradual creation. Nor is there even in such a passage as this: "From air and water, from heights and depths, I see the animals coming nearer to man, and step by step approximating his form. The bird flies in the air; every deviation of its structure from that of the quadruped is explicable from its element. The fish swims in the water: its feet and hands are transformed into tail and fins," etc. (Bk. II., ch. 3). If Herder had not elsewhere seemed to deny such a theory, we might at first sight be disposed to construe this passage as an assertion of the literal transformation of species—a Lamarckian sort of transformation, due to the adaptation of organs to needs. But when the words are closely scrutinized it is evident that they require no such interpretation. They say no more than that animals came into being in a progressive order in which the human type was steadily approximated, and in which each form was adapted to its environment.

2. In this connection, Herder liked to dwell upon the homologies of form and structure observable in all vertebrates, and indeed, as he thought, in all creatures, even those that are outwardly most dissimilar. There is a certain *Hauptform* or *Hauptplasma* in which the whole animal kingdom agrees. "It is undeniable that, amid all the differences of the living beings on the earth, a certain uniformity of structure and, as it were, a standard form, appears to prevail, which yet is transformed into the richest diversity. The similarity of the skeletal structure of land animals is obvious; . . . the inner structure makes the thing especially evident, and many outwardly uncouth forms are in the essentials of their internal anatomy exceedingly like man. The amphibia deviate farther from this standard; birds, fishes, insects, aquatic animals—the last of which merge in the vegetal or inorganic world—deviate still farther. Beyond this our eyes can not penetrate; but these transitions render it not improbable that in marine forms, plants, and even in the so-called inanimate things the same basis of organization may rule, though infinitely more rude and confused. In

the eye of the Eternal Being, who sees all things in one connected whole, it may be that the form of the ice-particle, as it is generated, and that of the snowflake that is formed upon it, may have an analogous resemblance to the formation of the embryo in the womb. We can therefore accept it as a general law that, the nearer they approach man, the more do all creatures resemble him in their essential form; and that Nature, amid the infinite variety which she loves, seems to have fashioned all the living things upon our earth after a single original model (*Hauptplasma*) of organization'' (Bk. II., ch. 4).* Herder had also learned from the comparative anatomists that it is a corollary to this similarity of structure that organs which function usefully in certain species appear also in other species where they have little or no apparent use or function; in other words, he knew of the existence of vestigial and rudimentary organs. ''What Nature had given to one animal as a merely accessory feature (*Nebenwerk*) she has developed into an essential feature in another; she brings it into plain view, enlarges it, and makes the other organs—though still in perfect harmony—subservient to it. Elsewhere again these subordinate parts predominate; and all organized beings appear as so many *disjecti membra poetæ*. He who would study them must study one in another; where an organ appears neglected or concealed, let him turn to some other creature in which Nature has perfected and plainly displayed it'' (*loc. cit.*).

3. Herder had further learned from Buffon that, within the limits of the specific type, a species may vary widely under differing climatic influences. 'Those species that inhabit nearly all parts of the globe, are differently formed in almost every climate,' etc. (Bk. II., ch. 3).

4. The author of the 'Ideen' also recognized, and frequently dilated upon, that fact in nature which later suggested the specifically Darwinian form of the theory of descent—the fact, namely, that nature turns out more aspirants for life than she can provide with the means of living, and that there results from this situation a universal struggle for existence between species and between individuals. Herder had, in fact, been profoundly impressed by the way in which the life-processes of nature seem to be the expression merely of a blind, striving *Wille zum Leben* (in the language of a later school), careless of the single life, tending only to the production of the greatest possible number of living beings, each of them competing with all the others. The discovery of this impressive and sinister aspect of nature was, certainly, the main source, alike of the most important scientific hypothesis

* This passage is given in part in 'From the Greeks to Darwin'—being the only citation from Herder there given; but the translation is singularly inaccurate, and in one place makes Herder appear to say the opposite of his real meaning.

of the nineteenth century, and of certain of the most significant and characteristic developments of nineteenth century philosophy—especially of philosophical pessimism. The emphasis which Herder lays upon this class of facts is therefore interesting and noteworthy: "Where and when each being *could* arise, there it arose; energies (*Kräfte*) pressed in through every gate of entrance and formed themselves to life" (Bk. X., ch. 2). "Nature employs infinitely many germs; . . . she must needs therefore reckon upon some loss, since all things crowd one another (*alles zusammengedrangt ist*), and nothing finds room completely to develop itself" (Bk. II., ch. 2). "The whole creation is at war, and the most conflicting powers lie close to one another. . . . Each being strives with each, since each itself is hard-pressed for life; it must save its own skin, and guard its own existence. Why does nature act thus? Why does she thus crowd her creatures one upon another? Because she aimed to produce the greatest number and the greatest variety of living things in the least possible space; so that one subdues another, and only through the equilibrium of opposing powers is peace brought about in the creation. Every species cares for itself as if it were the only one in existence; but by its side stands another which keeps it within bounds; and it was only in this adjustment of warring species that creative nature found the means of preserving the whole" (Bk. II., ch. 3). In all this Nature (for Herder almost invariably personifies) takes no account of the individual, but rather sacrifices him ruthlessly to her 'one great end, which is—not the little end of the sentient creature alone, but—the propagation and continuance of the species.' And in this connection Herder anticipates Schopenhauer in picturing the pleasures of the love of the sexes, and the romantic illusions connected with that love in man, as merely a subtle trick whereby nature cajoles the individual to sacrifice himself to her larger aim. Schopenhauer's famous chapter on the 'Metaphysics of the Love of the Sexes' is little more than an amplification of a passage in the second book of the 'Ideen.' Always, Herder perceives, when the reproduction and increase of life is at stake, nature turns Machiavelian, and plays upon the egoism of the individual for her own very different ends. "It is," he writes, "particularly humiliating to man that in the sweet impulses which he terms love, and to which he attributes so much spontaneity, he obeys the laws of nature almost as blindly as a plant. . . . Two creatures sigh for each other, and know not for what they sigh; they languish to become one, which dividing nature has denied; they swim on a sea of deception. Sweetly deceived creatures, enjoy your time; yet know that ye accomplish not your own little dreams, but, pleasantly compelled, the great aim of nature. . . . As soon as she has secured the species, she suffers the individual gradually to decay. Hardly is the season of love over

before the stag loses his proud antlers, the bird its song and much of its beauty, the plants their fairest colors. The butterfly sheds its wings and expires, while alone and unweakened it might have lived through half the year. This is the course of nature in the development of beings out of one another; the stream flows on, though one wave is lost in the wave that succeeds it'' (Bk. II., ch. 2).

But although Herder thus clearly remarked these characteristics of nature's dealings, he did not deduce from them either the biological or the philosophical consequences which have since become so familiar. It did not occur to him to find in the facts of the over-production of organisms and the struggle for existence an explanation—such as Maupertuis had already proposed—of that progressive production and selection of more highly organized and better adapted beings, the reality of which he so fully recognized. Nor was he led, by his apprehension of a universal tendency to the maximum production of living things, to erect the notion of 'unconscious will' into the central conception of a metaphysical system.

5. In his accounts of the beginnings of human society, and of the moral instincts without which society could not exist, Herder points out that these beginnings were made possible and necessary by a prior peculiarity in the physiological constitution which distinguishes the human species—namely, by the greater length of the period of helpless infancy. This, of course, is an idea upon which many evolutionary moralists and 'sociologists' have latterly delighted to dwell. Herder clearly sets forth how the prolongation of infancy was the condition and the chief cause of man's moral nature—how it provided the true training school in which the featherless biped was fitted for the social state: "The first society arose in the paternal habitation, bound together, by the ties of blood, of mutual reliance, and of love. Thus to destroy the savagery of men and to habituate them to domestic intercourse, it was necessary that the infancy in our species should continue for some years. Nature held them together by tender bonds, so that they might not separate and forget one another, like the beasts that soon reach maturity. The father becomes the teacher of his son, as the mother has been his nurse, and thus a new tie of humanity is formed. Herein lay the ground of the necessity of human society, without which it would have been impossible for a human being to grow up, and for the species to multiply. Man is thus born for society; this the affection of his parents tells him, this the years of his longer infancy show'' (Bk. IV., ch. 6).

This conception, however, was by no means a new idea of Herder's own. It is, therefore a little curious to find the idea put forward by evolutionary writers of the end of the nineteenth century as a fresh and striking discovery. Even so learned a man as the late Mr. John

Fiske supposed it to be a great novelty, and even conceived that he himself was the original discoverer of it. In the preface to his 'Destiny of Man' Mr. Fiske writes: "The detection of the part played by the lengthening of infancy in the genesis of the human race is my own especial contribution to the doctrine of evolution, so that I feel somewhat uncertain as to how far that subject will be understood." But the thing had been detected, not merely by Herder, but also by Pope, some fifty years before him; and that Mr. Fiske should have forgotten the fact only shows how general are the misapprehensions which concern the history of biological conceptions. Pope wrote, in the Third Epistle of the 'Essay on Man' (1733):

> Thus beast and bird their common charge attend,
> The mothers nurse it, and the sires defend;
> The young dismissed, to wander earth or air,
> There stops the Instinct, and there ends the care.
> A longer care man's helpless kind demands,
> That longer care contracts more lasting bands . . .
> Still as one brood, and as another rose,
> These nat'ral love maintained, habitual those:
> The last, scarce ripened into perfect man,
> Saw helpless him from whom their life began;
> While pleasure, gratitude and hope combined
> Still spread the interest, and preserved the kind.

Pope got the suggestion of this from one of Bolingbroke's 'Fragments'; but Bolingbroke had missed the main point, which Pope, in this case more original than his guide, clearly perceived. "If men," Bolingbroke had written, "come helpless into the world like other animals; if they require even longer than other animals to be nursed and educated by the tender instinct of their parents; it is because they have more to learn and more to do; it is because they are prepared for a more improved state and for greater happiness."

Bolingbroke failed to see that the most important consequence of the greater length of human infancy lay in its effect, not upon the child, but upon the parent—in creating the necessity for a steady and self-sacrificing affection and for a habitual subordination of immediate and personal aims to remote and disinterested ones. It may be, then, that to Pope should be given the credit of having first called attention to the relation between the lengthening of infancy and the evolution of social morality. It can hardly be doubted that it was the passage in Pope's poem that suggested the idea to Herder.

6. In all these cases the receptive and pregnant mind of Herder had grasped and elaborated separate ideas which have since become familiar parts of the general body of evolutionary theory. But did he accept the essential doctrine of evolution itself? Did he believe in the mutability of species and in the literal descent of man from lower

forms of life? If I am able to interpret his utterances correctly, he did not; on the contrary, he seems to have been at pains to express his dissent from such a doctrine,—which, as we have seen, was familiar enough to the men of science of his time. There are several distinct passages in the 'Ideen' in which Herder discusses the relation of man to the animal kingdom; and, in order that the reader may have the means of deciding for himself what Herder's position was, I will cite them at some length. "There are those," he says (Bk. III., ch. 6), "who have, I will not say degraded man to the rank of a beast, but have denied to him the character of his race, and would make him out to be a degenerate animal (*ausgeartete Thier*) which in striving after a higher perfection has wholly lost the distinctive qualities (*Eigenheit*) of its species. This, however, is manifestly contrary to the truth and to the evidence of natural history; man obviously has characteristics that no animal possesses, and performs actions of which both the good and the evil belong to him alone. . . . Since every animal remains true upon the whole to the character of its species, and since we alone have free will instead of necessity for our ruling power, then this difference must be investigated as a fact—for fact it undeniably is. The other questions—how man came by this distinctive characteristic; whether it was his from the beginning, or is adventitious and acquired: these are questions of a purely historical sort. Now, setting aside all metaphysics, let us confine ourselves to physiology and experience." Herder then points out the anatomical peculiarities of man, particularly those which, as Daubenton had shown, are connected with his greatest peculiarity, the upright attitude. And in view of these considerations Herder concludes thus: "Would the human animal, if he had been for ages in an inferior state—and if he had been formed as a quadruped in his mother's womb, with wholly different proportions—would he have left that state of his own accord and have raised himself to an erect posture? Out of the faculties of a beast, which would ever be drawing him backward, could he have made himself a man, and, even before he became a man, have discovered human speech? If man had ever been a four-footed animal, if he had been such for thousands of years, assuredly he would remain such still; and nothing but a miracle of new creation could have made him what he now is. Why, then, should we embrace unproved, nay totally self-contradictory, paradoxes, when the structure of man, the history of his species and, as it seems to me, the whole analogy of the organization of our earth, lead us to another conclusion? No creature that we know has ever departed from its original organization and adapted itself to another contrary to it; for it can operate only through the powers that inhere in its organization, and Nature is abundantly able to hold each living being fast in that state to which she has assigned it. In man everything is adapted to the form he now

bears; from this everything in his history is explicable; without it nothing is capable of explanation. . . . Why should we humble in the dust the crown of our high calling, and shut our eyes to that central point in which all the radii of Nature's circle seem to converge?"

In a later passage (Bk. VII., ch. 1) Herder directly discusses, only to reject, the theories of those (he probably has Monboddo especially in mind) who assert a kinship, or an identity of species, between the apes and man. "I could wish," he writes, "that the affinity of man to the ape had never been urged so far as to cause people to overlook, in seeking a graded scale (*Leiter*) of being, the actual steps and intervals without which no scale can exist. What, for example, can the rickety orang-outang explain in the figure of the Kamchatkan, the pigmy chimpanzee in the size of the Greenlander, the pongo in the Patagonian? for all these forms would have arisen from the nature of man if there had been no such thing as an ape upon the earth. . . . In point of fact, the apes and man were never one and the same species (*Gattung*). For each race nature has done enough, to each she has given its own proper heritage. The apes she has divided into as many species and varieties as possible, and extended these as far as she could. But thou, O man, reverence thyself! Neither the pongo nor the gibbon is thy brother; the American and the Negro are. These then thou shouldst not oppress nor kill nor rob, for they are men like thee; but with the ape thou canst not enter into fraternity." Herder expresses himself in a similar vein in a preface which he wrote for a German translation (1784) of the work in which Lord Monboddo set forth, among other things, his theory of the close relationship of man and monkey. Herder praises cordially Monboddo's taste for ancient art, and his large and philosophical way of dealing with the problem of the origin and development of human language; but he warns the reader against Monboddo's views on the orang-outang. The opinion that '*Affe und Mensch ein Geschlect sei,*' Herder marks as 'an error which even the facts of anatomy contradict.'

In another chapter of the 'Ideen' Herder speaks of the transitions (*Uebergange und Ueberleitungen*) and metamorphoses (*Verwandlungen*) through which nature leads the successive orders of animals, in a fashion which seems at first sight plainly to imply the derivation of higher from lower species by ordinary descent; yet in the same paragraph he pauses to insist upon the fixity of specific types: "It may appear that such transitions are incompatible with the definiteness of form to which every species remains true, and in which not the smallest bone undergoes alteration. But the reason for this invariability is apparent; since every creature can receive its organization only from other creatures of its own species. Our orderly Mother Nature has thus plainly predetermined the way by which any organic power

should come into existence (*Wirksamkeit*); and thus nothing can escape from its once-determined form'' (Bk. V., ch. 3).

It is hard to see how any reader of Herder's generation could have understood these utterances, when taken all together, in any other sense than as an assertion of the essential immutability of species and a denial of man's descent from simian or any other animal ancestors. It would appear then, that Herder never fully recognized that—as Kant put it—'the similarity of form in animals (such that they seem to be make after a common prototype) confirms the supposition that they have an actual blood-relationship, through descent from a common parent.' How, in the absence of such an hypothesis, Herder would have explained the gradual appearance of progressively higher forms is, undeniably, somewhat incomprehensible. But the truth is that his whole treatment of the subject is poetical, vague and not very careful of consistency, rather than explicit, definite and scientific. The theory of descent was, at the time he wrote, almost a commonplace of current biological discussion; but his attitude towards it was certainly ambiguous, and apparently hostile. The author of the 'Ideen zur Geschichte der Menschheit' may almost be called the father of the modern philosophy of history; but he can not unqualifiedly be called a pioneer of modern evolutionist biology.

IV. *Monboddo.*—The author of the work that called forth Herder's mingled admiration and criticism, James Burnett, Lord Monboddo, has been a good deal neglected by the historians of evolutionism; and, in spite of the fact that he was perhaps the first to make widely familiar to the British public the doctrine that man is descended from ape-like ancestors, it is doubtless true that his can not be considered a very serious contribution to the progress of zoological knowledge. This learned, original and whimsical judge is a highly picturesque and interesting figure in the literary history of Scotland in the eighteenth century. He was one of the conspicuous leaders of the intellectual society of Edinburgh at a time when the Scotch Athens—even while Jacobite uprisings still threatened—was one of the most notable seats of scientific and philosophical inquiry in Europe. In the circle of Monboddo's intimates were such men as David Hume; Adam Smith; Hutton, the founder of modern geology; Black, originator of pneumatic chemistry and of the theory of latent heat; Robertson, the historian; Lord Kames; Dugald Stewart, and, among the men of letters, Home—a dramatist whom Monboddo preferred to Shakespeare—and Fergusson. Lord Monboddo played the host to Burns in Edinburgh, and to Johnson at his ancestral country-seat—the conversation of the two great men on this latter occasion being recorded with great gusto by Boswell, who dearly loved to see the sparks fly at the contact of opposing

minds. In order to promote intellectual conviviality among his learned fellow townsmen, Monboddo introduced the innovation of late dinners —for his literary suppers, we are told by one who attended them, 'had all the variety and abundance of a principal meal,' and were modeled after the symposia of the ancients. In this society, so distinguished for scientific attainments and for original theories in natural science and philosophy, Monboddo had the reputation of being one of the most learned and most original. His speculations about the origin of language were only less notable, as a piece of pioneering in a new science, than was the work of Smith, of Hutton and of Black; and he had the insight to suggest—though only in a private letter—the theory of the common descent of the European tongues and Sanscrit, a language then newly made known to the Occident by his correspondent, Sir William Jones. But it was felt by most of Monboddo's British contemporaries that he pushed originality in theorizing to the point of fantastic absurdity when he declared that civilized man is akin to the orang-outang and a descendant of progenitors that lacked speech and possibly had tails. The Judge's chapters on the orang-outang sent learned Britain into inextinguishable laughter, and many were the poor witticisms made at his expense. The most vigorous and most amusing of all his critics was the great representative of a common-sense conservatism, Dr. Johnson. Gibes and invectives directed against the author of so ludicrous and so scandalous a doctrine are constantly recurring in the pages of Boswell: "Sir, it is as possible that the orang-outang does not speak, as that he speaks. However, I shall not contest the point; I should have thought it impossible to find a Monboddo; yet he exists." "It is a pity," said Johnson again, "to see Lord Monboddo publish such notions as he has done; a man of sense and of so much elegant learning. There would be nothing in a fool doing it; we should only laugh; but when a wise man does it, we are sorry. Other people have strange notions, but they conceal them; if they have tails, they hide them; but Monboddo is as jealous of his tail as a squirrel." But Johnson's final objection is expressed in these words: "Sir, it is all conjecture about a thing useless even if it were known to be true. . . . Conjecture as to things useful is good; but conjecture as to what it would be useless to know, such as whether man went on all four, is very idle." The intellectual history of the century that followed constitutes an ironical commentary on this dictum of the great eighteenth century conservative.

Monboddo's opinions concerning the descent of man are expressed most at length in the first volume of the 'Origin and Progress of Language,' published in 1773; some further hints of them may be found here and there in the letters of Monboddo recently collected and

edited by Professor Knight.* Those opinions are entirely incidental to his theory of language. Monboddo nowhere discusses the general biological question of the transformation of species, and possibly did not believe in the transformist doctrine as such—so that it is perhaps too much to call him, with Professor Knight, 'a virtual evolutionist, holding an honoured place between Lucretius and Darwin.' The main contention of his book concerns the evolution of man's language, not of man himself, and is to the effect that language can have arisen only after man had for some time lived in the political state, 'which state is not natural to man any more than the language to which it gave birth.' In order to establish such a theory it is desirable, if not essential, to point to instances of societies of men living without language; and it is at this juncture that Monboddo meets the difficulty by bringing forward his doctrine about the orang-outang.

That doctrine is that man and the orang-outang are one and the same species. What the orang-outang is our ancestors were. The orang-outang and chimpanzee are varieties of men that have failed to acquire the art of speech; or—what comes to the same thing, for Monboddo—our ancestors were a community of orang-outangs who succeeded in acquiring that art. It is evident that in such a contention a belief in transformation is not necessarily implied; in fact, in order to establish our descent from the orang, Monboddo seems to think it necessary to establish strict identity of species—thus implying that species can not descend from other species. In the 'Origin and Progress' he explicitly declines to generalize his doctrine. "Though I hold the orang-outang to be of our species, it must not be supposed that I think the monkey or ape, with or without a tail, participates of our nature; on the contrary, I maintain that however much his form may resemble ours, he is, as Linnæus says of the Troglodyte, *nec nostri generis nec sanguinis*." In one of the letters in Professor Knight's volume, however, Monboddo writes: "I think the simian race is of kin to us, though not so nearly related (as the orang-outang). For the large monkeys and baboons appear to me to stand in the same relation to us that the ass does to the horse, or our gold-finch to the canary-bird." What he conceived that relation to be, he does not tell us; but it may fairly be supposed that he was thinking of collateral descent from a common ancestral species.

Monboddo's statements of his position, and his arguments for it, are made somewhat ambiguous by the fact that he, like Herder, is not altogether clear as to what constitutes identity of species, though he notes Buffon's definition, which makes the only test of difference of

* 'Lord Monboddo and his Contemporaries,' London and New York, 1900. My citations from Monboddo are taken from the second edition of the 'Origin and Progress,' Edinburgh, 1774.

species in animals to be the infertility of their offspring. Monboddo thinks we can find other criteria that are as conclusive and easier to apply. We are entitled, he holds, to assign to the same species all animals which possess in common a large—but an undefined—number of similar characteristics, provided that these characteristics appear to be essential and 'such as have great influence upon their nature.' Now the orang-outang greatly resembles man in his external form, his anatomical structure, and even in his 'inward principle,' the 'natural habits and dispositions of the mind.' Upon this last point of resemblance Monboddo particularly likes to dilate; it seems to be his principal criterion of unity of species. The reason why the baboons and other monkeys are, in the published treatise, denied kinship with us is because, similar to us in other respects, they lack this intellectual resemblance. Of the intellectual parts and the charm of temperament of our brother the orang, Lord Monboddo exhibits an extremely exalted opinion: "The orang-outang has the human intelligence, as much as can be expected in an animal living without civility or arts: he has a disposition of mind mild, docile and humane: he has the sentiments and affections peculiar to our species, such as the sense of modesty, of honor and of justice; and likewise an attachment and friendship to one individual so strong in some instances that one friend will not survive the other: they live in society and have some arts of life; for they build huts and use an artificial weapon for attack and defence, viz., a stick; which no animal merely brute is known to do. They show also counsel and design, by carrying off creatures of our species for certain purposes, and keeping them for years together without doing them any harm; which no brute creature was ever known to do. They appear likewise to have some kind of civility among them, and to practice certain rites, such as that of burying the dead." The female orang-outang, it appears upon the testimony of Bontius the Batavian physician, is modest to the point of prudery; and some of the species are of so fine a sensibility that they shed tears copiously upon being parted from persons to whom they have become attached.

Monboddo's arguments for his theory come somewhat nearer to the proper homological proofs of evolution when he points out that the *os coccygis* is plainly nothing but a rudimentary and abbreviated tail, and that the civilized man thus carries about upon him a tell-tale member which hopelessly betrays the secret of his ancestry. Monboddo seems to opine that the loss of the tail by mankind has been comparatively recent, and that it is by no means universal; in justification of this opinion he adduces a number of travelers' stories that are more diverting than plausible. There is, for example, the story told by a Swedish sailor—whose credibility was vouched for by Linnæus—who saw on one of the Nicobar Islands 'a race of men that trafficked and

used the art of navigation, who had tails like those of cats, and which they moved in the same manner.' This narration is perhaps exaggerated, Monboddo admits; but 'that there are men with tails is a fact so well attested that it can not be doubted.' For, setting aside all travelers' reports, and the testimony given by the ancients to the existence of races of *homines caudati*, he himself had known of a Scotch schoolmaster in Inverness who had a tail half a foot long. The man prudently kept his unusual endowment concealed during his lifetime, but it was discovered after his death:—of all of which Lord Monboddo offers to bring legal evidence. The superficial and the dogmatists, he adds, will no doubt think these stories very ridiculous, 'but the philosopher, who is more disposed to inquire than to laugh and deride, will not reject it at once as a thing incredible that there should be such a variety in our species, as well as in the simian tribe which is so near akin to us.'

All these arguments *a posteriori* are really irrelevant to Monboddo's main thesis about the relation of man to the orang-outang; since those particular 'simian tribes' with which alone he declares man to be akin (*i. e., satyrus* and *troglodytes niger*) are destitute of tails, and have an even more rudimentary coccyx than man. The fact that men had tails would, from his own standpoint, rather tend to show that man and orang belonged to different species, than that they belonged to the same. Of this Monboddo seems to be not unaware, for he introduces his stories of tailed men as a sort of digression, and not as a part of his principal argument. As it stands, his discussion about tails seems rather to resemble the caudal vertebræ with which it is concerned—it suggests a good deal, but is not designed to bear any of the weight of proof, and is a relatively functionless appendage to the main body of his theory.

The comparative crudity and superficiality of Monboddo's speculations about the descent of man are one indication of the fact that, down to the end of the eighteenth century, the country of Darwin had made far less progress in this part of biology than had France and Germany. For Monboddo's book seems to be the nearest approach to an assertion of the mutability of species and the derivation of man from animal ancestors which was made by any generally read English writer, until the 'Zoönomia' of Dr. Erasmus Darwin appeared in 1794.

ITALIAN AND OTHER LATIN IMMIGRANTS.

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ITALIAN immigration was insignificant until 1880. In that year we received about 12,000 Italian immigrants, and since that time the number increased steadily until the year 1891, when 76,000 arrived in the United States. This number was not exceeded until 1899, when the total yearly Italian arrivals began again to increase and in the past year (1903) reached the astounding total of 233,546. Eighty-five per cent. of this total was made up of southern Italians. The following tables indicate the distribution of Italians landed in the United States in 1903:

NORTH ITALIANS.

State.	Number of North Italians.	Ratio to Total North Italians Landed.
New York	9,452	25 per cent.
Pennsylvania	7,461	20 "
California	5,369	14 "
Illinois	3,163	8 "
Massachusetts	2,233	6 "
Connecticut	1,242	3.5 "
Michigan	1,209	3.5 "
New Jersey	1,158	3 "
All other states	6,142	17 "
Total	37,429	100 per cent.

SOUTH ITALIANS.

State.	Number of South Italians.	Ratio to Total South Italians Landed.
New York	91,774	47 per cent.
Pennsylvania	42,696	22 "
Massachusetts	13,731	7 "
New Jersey	9,970	5 "
Illinois	6,637	3 "
Connecticut	6,301	3 "
Ohio	5,372	3 "
Louisiana	4,815	2 "
Rhode Island	3,515	2 "
West Virginia	2,096	1 "
All other states	9,210	5 "
Total	196,117	100 per cent.

In considering Italian immigrants it is necessary to recognize the differences existing between northern and southern Italians. The northern Italian is taller, often of lighter complexion, and is usually in a more prosperous condition than his brother from the south. The northern Italian is intelligent, can nearly always read and write, and very often is skilled in some trade or occupation. He compares favorably with the Scandinavian or German, and his desirability as an im-

migrant is seldom questioned. He usually leaves Italy through the representations of friends in this country, and therefore comes here with a definite purpose, and is not at the mercy of a 'padrone.' On the other hand, the southern Italian, short of stature, very dark in complexion, usually lands here almost destitute. His intelligence is not higher than one could imagine in the descendant of peasantry illiterate for centuries. He can seldom read and write, and invariably is an unskilled farm laborer. He has little money and often has no definite purpose, and naturally must depend on some one who speaks his language. In this way he falls into the hands of the 'padrone.'

The early Italian immigrants were of the itinerant class—rag-pickers, organ-grinders, etc., but after 1870 these were succeeded by the Italian peasantry of the south, who were forced by economic conditions and poverty at home, to emigrate. They came here at first to supply the demand for unskilled laborers, occasioned by the great industrial activity following the civil war. In a majority of instances these immigrants were brought here and taken charge of by padroni and Italian bankers and were sent by the padroni in every direction where their labor was needed. The Italian peasant is peculiarly susceptible, by reason of his ignorance, to any system of blackmail or extortion. In Italy, for years the Camorristi terrorized and imposed tribute upon the ignorant peasantry, and it was natural that, following this experience, they should continue to be victims to the same practises in another form. Italians of superior educational and intellectual attainments in America have been as unscrupulous and vulture-like in the treatment of their ignorant brethren, as were the Camorristi in the zenith of their power. The extortioners in America have been known as padroni and bankers. Just when the padroni first appeared in America is open to question. He was much in evidence toward the close of the civil war, when the demand for laborers was out of all proportion to the supply. At this time contractors and manufacturers could contract in Europe for large numbers of laborers without violation of law, by reason of legislation enacted in 1864. This privilege gave the padroni their opportunity. Previous to that time their importations were almost all peddlers, organ-grinders, harpers and other itinerant musicians.

In the beginning the American employer of labor, in his anxiety to secure a large amount of cheap labor for some particular enterprise, would apply to an Italian immigration agent for a certain number of men. The agent, or padrone, in turn would secure the men through sub-agents in Italy and have them shipped across on prepaid tickets, for which he charged a liberal commission. Upon their arrival, the agent, or padrone, boarded them at immense profit, pending their distribution here, and received his compensation from the American contractor, who took it out of their prospective wages. The contract of

supplying the workmen with food and shelter while working was often in the hands of the same man. Sometimes the padrone was also banker, and, if so, he charged exorbitant rates for sending the laborer's meager savings to Italy. He also counted on the chance, which came to him in a majority of cases, of making a profit on their return tickets to Italy.

Later these agents, or padroni, became independent of the American contractors. Instead of procuring men for the contractor and depending on him for their remuneration, they became wholesale importers on their own account and induced large numbers to emigrate from Italy, by promises which seemed to open fairyland to the Italian 'cafone.' They always insisted on a contract for one to seven years. The men were farmed out to whoever would pay the padrone for their labor, usually as laborers with pick and shovel. The padrone boarded his people, charged them for all necessary things at exorbitant rates, and at the end of the year the laborer had very little coming to him. Nor was the system of slavery confined to men. Women were included and frequently placed in houses of prostitution. Little children were brought here in the same way and forced to black boots or sell newspapers, flowers or fruits, for the benefit of the padrone.

The traffic in helpless humanity, as carried on by padroni twenty-five years ago, has been gradually checked. The importation of women and minor children was first stopped by governmental action, aided by philanthropic societies. The wholesale importation of labor was not stopped, however, until after the passage of the first contract labor law in 1885. The enforcement of this law, aided by the hearty cooperation of the Italian government, finally ended the degrading practise. The padrone system, as it once existed, is now a matter of history. The skeleton of the padrone exists, but he is now nothing more than an employment agent, a high-priced and unlicensed employment agent, it is true, but with less of the absolute power over the peasant, which in the past made their relations those of master and slave.*

Probably the so-called Italian banks are as potent a means of extortion as the padrone system itself. The padrone is sometimes a banker, and, if not, is always in league with one. Between them they take advantage of the child-like credulity and ignorance of the Italian laborer, and fleece him of his last dollar.

The southern Italian concerns us most in considering the desirability of the Italian immigrant. His northern brother need give us no more concern than the representatives of the United Kingdom, Germany or Sweden. The most striking feature presented by Italian

* The padrone system as it exists to-day is graphically described by John Koren, Esq., in a bulletin published by the Department of Labor.

immigration is the comparatively small number who engage in farming, despite the fact that 85 per cent. of this immigration is made up of the peasant class. This phenomenon can be explained by the fact that the immigrant is both poor and ignorant. His poverty forces him to accept whatever work is offered. His ignorance and inability to speak our language prevent him from learning the possibilities of American agriculture. He looks with distrust on an agricultural occupation, as likely to be unremunerative and enslaving, as he found it at home. Then the rural life at home was very different from rural life here. In Italy the peasants for the most part live in big villages or towns, and go to their work early in the morning, returning to their home in the evening, so that when the day's work is done they can rejoin their family among thousands of their own kind.

The crowding of Italians into our large cities can be understood if one studies the padrone system and padrone banks. The poor, ignorant laborer is at the mercy of the padrone and banker, and if he could leave, does not know where to go. He has no friends to show him the way, to inform him of the homestead law or of the wages paid farm laborers. But he finds friends (?) speaking his own language in the great city who will get him a 'job,' and so he stays in the city. He is sent out on contract labor and probably in the fall, when the work is done, arrives in the city again with very little money to face the winter. Often he finds it cheaper to pay the steerage rate and go back to sunny Italy than to stay in cold New York, where fuel is a necessity and provisions dear.

The Italian as an agricultural immigrant is a success, and the regrettable feature of Italian immigration is the small percentage who go to rural communities. Italian agricultural colonies in and around Vineland, N. J., are prosperous and growing. The Italians in Texas have been uniformly successful in rice and cotton culture, truck farming and vine growing. They have been very valuable in Louisiana, Mississippi and other southern states, as a substitute for the unreliable, shiftless negro. Their success in California, where they found the climate particularly suited to them and their favorite occupation, vine and fruit growing, has been one of the features of the development of California. The report of the Italian Chamber of Commerce, San Francisco, 1897, gave 47,625 Italians living in the 56 counties of California, almost all engaged in agriculture, owning 2,726 farms. Eight hundred and thirty-seven business concerns had a capital of $17,908,-300, the total capital for Italian business men, ranchers and farmers aggregating, according to this report, $114,325,000.

Italians have been established near many of our largest cities upon truck farms, and in almost every instance are successful. The Italian colonies in Alabama are thriving and prosperous communities, with schools and churches.

The average stature of Italians is very much below the medium, but, nevertheless, they are wiry and muscular and capable of prolonged physical exertion. The country-bred Italian bears the insanitary conditions of the tenement houses very badly. He succumbs to disease as a result of tenement house conditions more readily than the Hebrew, who for generations has been a dweller in the crowded insanitary districts of large towns and cities, and has acquired a certain degree of resisting power against diseases due to overcrowding, filth and lack of pure air and sunlight. Italian children reared in the Italian quarter of New York, Boston, Philadelphia or Chicago are prone to tubercular disease and rickets, and compare unfavorably with children brought up in Sicily or Italy. Consumption is frequent among tenement-house Italians, although extremely rare in recently arrived immigrants.

Mentally the Italian immigrant is what might be expected of peasantry whose average illiteracy is 48 per cent. However, the possibilities of the Italian peasant, properly educated, are very promising. They are very quick to learn, have a deftness of hand which adapts them to trades requiring manual skill, and their artistic sense is always developed, though it sometimes does violence to the esthetic color sense of hyper-critical Americans.

The moral standard of the Italian family is very high, and Italian women are deservedly noted for the homely virtues, which make womanhood, of whatever nationality, revered.

The crimes charged to the Italians are usually crimes of violence, actuated by revenge for real or fancied wrongs. These are outgrowths of the custom of taking the law in their own hands in a country where the poor had little or no redress from the law. But in the aggregate of crime the Italian, by reason of his sobriety, presents a better record in this country than many of the races commonly classed as desirable. The Italian seldom becomes a public charge, because of his willingness to work at any kind of labor that offers. He does not become pauperized. He applies for and receives charity less often than many of our other city-dwelling immigrants. He is frugal and, in spite of the robbery to which he is subjected by padrone or banker, manages to save some of his earnings. If he has no other prospect, when winter, lack of work and poverty stare him in the face, he usually has the price of steerage passage to Italy, and migrates to reappear at some more opportune season. This migratory tendency of the Italian laborer has caused a great deal of comment upon his value to the country. There is little doubt that the Italian goes back and forth between Europe and America more than any other people. They have earned the title of 'birds of passage' by their habit of flitting back and forth and have been accused of sending vast sums of money home and, in many instances, of going home to live in luxury on the money they earned in America.

Instances are recorded where Italians have arrived in America as immigrants, who admitted having been here six or seven times before. It is certain, however, that the Italian laborer, in a majority of instances, gradually gets accustomed to American ways and finds things at home more strange on each succeeding visit, and eventually loses all desire to live permanently in his native land. He goes back and forth to see his old parents, to escape destitution in a New York tenement when out of work, or to arrange, if he is prosperous enough, to bring his family here.

Nothing illustrates the growing permanency of our Italian immigrants with greater force than the ever increasing proportion of women and children now recorded among Italian immigrants. Whenever the Italian is able to shift for himself, when he is independent of the padrone and Italian banker, he is likely to be a permanent and useful citizen. The sums alleged to have been sent to Italy by Italian laborers here have been grossly exaggerated, and it is doubtful if any Italian, successful enough here to acquire a competence, could escape Americanization, or have any desire to live in Italy after having adopted American ideas of living. The Italian laborer sends money to Italy to his aged parents or to his wife, to help pay rent, taxes and other burdens at home. He does this from a high sense of filial or marital duty, for the Italian never forgets his duty to either parent or wife, and surely this devotion is commendable; but his desire in many instances is really to establish a home and bring his dependent ones here to live with him.

The Italian is gradually becoming independent of the padrone. He is also beginning to learn the splendid possibilities for independent effort in agricultural pursuits. That there is a great field for him is shown by his success wherever he has been led in the right direction. To make the Italian uniformly successful it is only necessary to lead him out into the country, away from the vitiated atmosphere of the tenement and slum. No place is better fitted for him than our southern states, and no immigrant is better fitted for playing a part in the development of those states than the Italian. He requires the pure air of the country and the geniality of the southern winter, and by his skill and industry in intensive farming, he can make the sandy soil of the pine land productive or reclaim the swamps and lowlands, which have lain fallow for years. He can give the southern planter his reliable thrifty labor to replace the erratic improvident negro, and can introduce and carry to perfection the vine growing and wine making, which have made southern California famous. These are some of the possibilities of the Italian immigrant, if properly directed, but his mode of life in the great cities, where the vast majority of Italians lives, presents quite a different picture. Here we find the 'Italian quarter,' which is responsible for most of the prejudice against

the Italian immigrant. In these colonies we see the Italian at his worst, physically and morally, but, as has been pointed out, he crowds the Italian quarter because there is no alternative for him, in his ignorance of our language and customs. Instead of being led into the country, where the labor is needed, he is induced to stay in the 'quarter' by his more fortunate countryman, padrone or banker, who expects to increase his profit thereby.

The philanthropists, Italians or Americans, who will direct the Italian to his proper place in the rural districts, will do a grand work for the Italian immigrant, for the states to which he will contribute his skill and labor and for humanity in general.

The Italians are the principal factor in our Latin immigration, but we also receive French, Spanish, Portuguese and Roumans.

Immigrants from France rank high as desirable additions to our population, but the desirability of French-Canadian immigration has been the subject of much discussion. Much of the disfavor into which the French-Canadians have fallen is due to their effect upon labor conditions in New England. It is estimated that from fifty to seventy thousand of these French-Canadians come to the New England factory towns, for temporary employment, each year. When the price of labor rises they come in large numbers and when the wages decrease large numbers return. It is said that many French-Canadian farmers send their families to Fall River and other New England towns to earn money and return with their savings to Canada. Their standard of living is very low and, as they regard their sojourn as temporary, they make little attempt to better it, but subject themselves to hardship and self-denial in order to increase the amount of money which they hope to take back with them to their Canadian homes.

The enforcement of the child labor laws and the reduction of the number of working hours for women, by the state of Massachusetts, has had a marked effect upon the unfair competition of the cheap child labor and unlimited working-day, which were features of the French-Canadian invasion. Organization of the French-Canadians has been beyond the power of the labor unions, and they are a factor in depressing wages in the textile trades, although the influence in this direction of the competition of native labor in the south must not be overlooked.

The French-Canadians are among the best lumber men and river drivers in the world, and have been valuable in this industry in northern Michigan and other border states. They are not very thrifty, and usually spend their money freely. After the timber is stripped off, they have more inclination to follow the receding timber line and live in the lumber towns than to take up the cleared land for farming.

In New England more of these people are becoming permanent

settlers than formerly, and among those who show an inclination to permanence, the standard of living is improving, in imitation of their English, Irish and American neighbors.

Portuguese immigration in 1903 amounted to over eight thousand souls. They have the highest proportion of illiterates of any European race, their percentage of illiteracy being about 70 per cent. They also bring less money *per capita* than most other races. In spite of these facts, a study of Portuguese immigration reveals many excellent qualities, and chief among these are their permanency, peaceable disposition, thrift and skill in fruit growing and truck farming. The behavior of Portuguese immigrants undergoing inspection at Ellis Island is characterized by extreme gravity and almost absolute silence. They present a striking contrast to the animated vivacious Frenchman or jabbering Italian, and after landing make quiet, law-abiding citizens. About 38 per cent. of the number landed last year were females, and nearly 25 per cent. were children, indicating the large number of families and their evident intention to settle permanently. Their distribution here is peculiar, and 93 per cent. of the total landed last year went to three states, Massachusetts, California and Rhode Island. They are practically the only race from southern, central or eastern Europe which does not send the majority of its immigrants to New York or Pennsylvania. The following table indicates the number and geographical distribution of Portuguese landed in 1903:

State.	Number Landed.	Ratio to Total Number Landed.
Massachusetts	5,691	68 per cent.
California	1,057	12.5 "
Rhode Island	1,029	12.5 "
New York	475	5 "
Connecticut	114	1.5 "
All other states	67	1 "
Total	8,433	100 per cent.

The Portuguese in Massachusetts and Rhode Island are engaged in fishing, market-gardening and fruit growing. They have taken up abandoned farms in those states, particularly in the Cape Cod district, and have been successful in agriculture where others have been discouraged. In California they have been very successful as fruit and vine growers. Their skill in intensive farming enables them to establish themselves upon tracts of land which are unproductive to ordinary agricultural crops and methods, and by truck farming and fruit growing they make a living upon farms neglected by native farmers.

Physically they are undersized, but are remarkably free from disease and physical defects. Seventy per cent. of the males are unskilled laborers, and their natural trend, unlike other southern Europeans, is toward the agricultural districts. Even the Portuguese fishermen

about Cape Cod are giving up this pursuit and taking up farms in that vicinity with their usual success. There is plenty of room for these agricultural Portuguese immigrants in this country, particularly in the south, and their coming will greatly increase the productiveness of any state with waste land, or farms that have been abandoned for a more fertile section.

Little need be said of Spanish immigration, which is small, but of excellent quality. Their total in 1903 was only 3,297. In striking contrast to their neighbors, the Portuguese, they exhibited over $50 *per capita,* and their illiteracy was only 9 per cent. They show less inclination to become permanent settlers, however, than the Portuguese, as evidenced by the small number of women and children among them. A large proportion was made up of merchants, professional men, students, marines and skilled mechanics, and less than 1,000 were classed as laborers.

The Roumanian, or Rouman, immigrants are classed as Latins, and in their appearance and speech resemble that group of peoples. The Roumanian people numbers about 5,000,000, most of them in Roumania. Roumans are also found in considerable numbers in Hungary, Transylvania, Bessarabia and the Balkan states. They are descended from a blended stock, made up of Roman colonists and disbanded soldiers, and the Illyrian and Thracian inhabitants of Macedonia at the time of the Roman conquest (146 B.C.). The whole of Macedonia was, up to the seventh century and the coming of the Slav, occupied by a Latin-speaking race. The Slavic conquest forced the Roumans in great numbers to their brothers north of the Danube, and many were carried farther by the wave of invasion—as far west as the Tyrol. The Roumans in Macedonia are skilled in metal working and the building trades, but we receive comparatively few Roumans from either Macedonia or Roumania. Eighty-five per cent. of our Roumanian immigrants come to us from Austria-Hungary—and they are practically all unskilled laborers. Although classed as Latins and speaking a Romance tongue, they show, in many cases, evidence of fusion with other races, Magyar and Slav. The Rouman type is short and dark, and they are usually free from disease and have a fairly good physique.

They bring very little money—less than ten dollars *per capita*—but, being unskilled laborers, seldom become public charges. They are an industrious people and possess in a marked degree the pride of race common to all peoples of Roman blood. In desirability these various Latin peoples might be rated higher than the Italians, but their numbers are relatively so insignificant that more extended notice is unnecessary.

THREE DECADES OF COLLEGE WOMEN.

BY FRANCES M. ABBOTT,
CONCORD, N. H.

THE following statements relate to the occupations, careers and matrimonial condition of the graduates of the first thirty classes of Vassar College, from 1867 to 1896, inclusive. The records of 1,302 women are included. The information is taken from the last general catalogue, which gives the history of all the classes to the end of the century; but the last four, 1897–1900, are not considered in this article.

The first question that everybody asks is, Do college women marry? The first ten classes, 1867–76, contain 323 members. Of this number 181, or 56.03 per cent., have married. The average age of a college woman at graduation is 22 years. Hence the age of these classes in 1900 averaged from 46 to 56 years—most of the members old enough to be grandmothers. It is quite possible that some of the living members may marry yet, for two instances were found in one class where marriage occurred 24 years after graduation; but making allowance for sporadic cases of this sort, 60 per cent. would probably include the complete marriage record of the graduates of this period.

These figures would seem to confirm the worst fears of those who, forty years ago, opposed the admission of women to college. It is difficult to make comparisons, because so many circumstances enter into the question of marriage. College women come from all sections of the country and from the most diverse social and pecuniary environment. The rate here given is undoubtedly less than that for the whole female population of the country, but perhaps not less than might be expected for a specialized and highly educated class.

The tendency of civilization seems to be toward comparatively late and few marriages. One can almost judge of the advancement of a people as a whole (the isolated villages of Miss Wilkins's stories are exceptional) by the number of single women. Females among savage races, as in the animal kingdom, are not allowed to remain unmated. It is an unusual thing in these days for a well-bred girl to marry under twenty. In our mothers' day such a course was eminently proper, and in our grandmothers' time girls married at fifteen or sixteen and afterwards bore that number of children.

As soon as a country becomes settled and its inhabitants used to material comforts and social privileges, the care and support of a family become a serious matter and early and hasty marriages are

discouraged. Whenever a variety of occupations is open to women, they need not marry for a livelihood and the ethical standard is raised. I think, however, the fact that a woman has an occupation is a less certain hindrance to marriage than many suppose. As will presently be seen from these records, the graduates who have taken up the most advanced work are quite as likely to marry as those who have not, and many of those who are best known to the outside world are both wives and mothers.

Still another fact may comfort the pessimists: Although less than three fifths of the first decade of Vassar women have entered matrimony, no other profession in any decade has attracted nearly so large a number. If marriage is not universal among college women, neither is teaching.

In the second decade, including the classes '77–'86, there are 378 graduates. The members of these classes in 1900, accepting the average age, ranged from 36 to 46 years. As might be expected, the marriage rate is somewhat less than for the preceding decade. Out of the whole number 191, or 50.53 per cent., have married. The next general catalogue would probably show a larger proportion. The third decade, 1887–96, contains 601 members. As '95 was the first Vassar class to graduate 100 members, a rate which since then has been steadily exceeded, it can readily be seen that half the members of this period were under thirty years when the census was taken. Its marriage rate has no value for general statistical purposes. Of the 601 members 169, or 28.12 per cent., were married in 1900.

The number of children next claims attention. These statistics are particularly valuable, for it is the first time any on this subject have been collected. The general catalogues of 1883 and 1890 contain no information on this point. The 181 marriages of the first decade have produced 361 children, or two to a marriage, a typical American family of the present day. In the second decade there are 191 marriages and 295 children, or 1.54 children to a marriage. It is fair to assume that this proportion will be increased. In the last decade there are 169 marriages and 135 children, an obviously incomplete record.

Although the number of children seems small in the first decade, which is the only one where the record may be regarded as measurably established, it must not be inferred that there are no large families among the alumnæ. The banner record in this respect belongs to a member of the class of '75, a widow with eight children. There are three graduates who have seven children each, in the classes of '71, '79 and '80, respectively. The member in '71, a small class of 21 members, 12 of whom have married, has nearly one quarter of the whole number of children (29) in the class. In the class of '79 three

mothers claim 19, or more than half of the 35 children which have resulted from the 18 marriages. In the family of the member from '80 six of the seven children are sons. There are nine mothers who have six children each, one in '69, '73 and '74 and two in '76, '78 and '79, respectively. In three of these families, the one in '69 and one of the two in both '76 and '78, the children are all boys. All this goes to show, what has so often been stated, that there is no such thing as an average person.

Now comes the most surprising fact in the whole record of this catalogue, and that is the preponderance of boys among the children. In the first decade there are 204 sons and 157 daughters, making the excess of the former nearly 30 per cent. At first this proportion seemed accidental, but though not so large in the succeeding decades, it appears constant. In the second decade there are 160 sons to 135 daughters, making the excess of the former 18½ per cent.; and in the third decade there are 73 sons to 62 daughters, or 19⅓ per cent. more boys than girls.

It is a well-known fact that in the normal birth rate the number of males slightly exceeds the females, by about five per cent. This is explained because of the greater mortality among boy babies. It is the intention of nature that the sexes upon arriving at maturity shall be about equal in numbers. But the fact that to any class of mothers should be born nearly one third more sons than daughters, as in the first decade, or almost one fifth more, as in the other two decades, suggests an interesting problem to the physiologist and the sociologist. Climate or material environment can not account for it.

Before leaving these matrimonial statistics, it may be worth while to compare them with those of the Harvard graduates, as set forth by President Eliot in his report of last year, which has not yet ceased to echo around the country. Dr. Eliot gave the records for six classes, 1872–77. Of the 881 members in those classes 634, or 72 per cent., had married. Though the proportion is considerably larger than that (56 per cent.) of the 323 Vassar women in the classes 1867–76, President Eliot considers it regrettably small. It is interesting to note that the average number of children is precisely the same, both in the Harvard and in the Vassar families, two to each. The 634 Harvard fathers report 1,262 living children. College women as a class have often been sneered at because so many of them do not marry, but if less than three fourths of college men marry, perhaps higher education may have an effect upon the individual quite as much as upon the sex.

Of the 1,302 Vassar graduates, 1867–96, there were 541 married in 1900. In the whole list there are but three second marriages, two of them in the class of '81, and no divorce indicated as such. But

one other fact remains to complete this record of vital statistics. In the first decade 63 members, or 19.19 per cent., have died. Of this number 36 were married and 27 unmarried, a ratio of four to three. This might indicate that matrimony is slightly unfavorable to longevity, as the ratio of those marrying to those not marrying is 14 to 11. But this impression is corrected in the following decades.

In the second decade the number deceased is 39, or 10.31 per cent. Of these 16 were married and 23 unmarried, a ratio of about two to three. As the number of married and single women in this decade is about equal, the death rate is decidedly in favor of the married. In the last decade 16, or 2.66 per cent., have died, four of them married, making the rate one to three, whereas the marrying rate is about seven to 18. This again shows a small balance in favor of the married. The whole number of the graduates who have died is 118, or 9.06 per cent.

Next to matrimony the profession that claims the greatest number of the alumnæ of Vassar is teaching. In this schedule are included all those who have recorded themselves as teaching, if only for a year. This may give an exaggerated impression of the number following teaching as an occupation; but I know of no way of establishing a definite professional record for a woman, because all roads, sooner or later, are likely to lead, if not to matrimony, to the domestic circle. From my own observation I should say that probably two thirds of every class at Vassar, immediately upon graduation, experiment more or less with pupils. Members of school boards will probably say that fully three thirds seek positions. My estimate may be more nearly correct, however, and of this two thirds, I doubt if more than one sixth, or one ninth of the whole, follow the profession for a considerable length of time, say ten or fifteen years.

Here are the records: In the first decade 128 of the 323, or 39.62 per cent. of the whole number, are recorded as teaching or having taught. Out of this list 46, or more than one third, have married, which in most cases, not all, has ended their public teaching. Several have resumed or taken up teaching on the death of their husbands, and sometimes when the husband is living. In the second decade there are 154 teachers, or 40.70 per cent. of the whole number. In this list 59, or again more than one third, have married. In the last decade, where we naturally expect to find the greatest number who have not severed their connection with the school-room, there are 304 teachers, or but 50.58 per cent. of the whole list, and even out of this half 52, or 17.10 per cent., were married in 1900.

A considerable number of these teachers have done advanced work. In the first decade there are twenty professors, officers and instructors in institutions belonging to the Association of Collegiate Alumnæ, an

organization which admits no colleges but those of the first rank. There are fifteen professors and instructors in other institutions. There are also thirteen principals, either of their own private schools or of endowed academies. This makes a list of 48; excluding ten duplicates, 38, or nearly 30 per cent., of the 128 teachers are of collegiate or principal rank.

This proportion of advanced rank holds good in the second decade, which contains 28 professors and teachers in colleges belonging to the Association of Collegiate Alumnæ. There are 21 professors, officers and instructors at other colleges and seven principals and preceptresses. Of the 56 just mentioned, excluding 11 duplicates, there are 45, or more than 29 per cent., of the 154 teachers of this decade, of collegiate or principal rank.

In the last decade it is not surprising to find that no graduate has yet attained to a professorship in a college belonging to the Association of Collegiate Alumnæ. There are, however, 26 teachers in the Association of Collegiate Alumnæ colleges, one principal and 14 professors and teachers in other colleges. These 41 instructors make 13.48 per cent. of the 304 teachers of this decade.

Next to imparting knowledge Vassar alumnæ seem to be fond of acquiring it. After the teaching profession no occupation or pursuit enlists so many graduates as that of advanced study. In the first decade 35 have taken the degree of A.M.; three, that of S.B.; and two, that of Ph.D. The strictly professional degrees will be mentioned later. There are also three fellows and three who have done graduate work at universities without degrees. Excluding ten duplicates, 36 members of the first decade have done graduate work. This is 11.11 per cent. of the whole number for this period.

In the second decade 29 have taken the degree of A.M.; one, that of S.B.; one, Ph.M.; and six, Ph.D. There are also two fellows and six who have pursued advanced studies at universities without taking degrees. Excluding ten duplicates, 35 members of the second decade, or 9.26 per cent., have done graduate work at colleges and universities.

In the third decade 36 have thus far taken the degree of A.M.; thirteen, that of Ph.D.; there are eight fellows and 42 advanced students. The Ph.D.'s are accredited as follows: Yale, 4; Cornell, Chicago and Bryn Mawr, two each; University of Geneva (Switzerland), Columbia and Harvard, one each. The last is recorded, not granted, as Harvard University, almost alone among the colleges of this country, does not yet confer degrees upon women. Excluding 13 duplicates out of the foregoing 99 names, 86 alumnæ of this decade, or 14.31 per cent., have done graduate work at American and foreign colleges and universities. In the class of '91, numbering but 36 members, there are five Ph.D.'s, almost one seventh of the whole.

The average of those doing graduate work for the whole thirty years is 12.05 per cent. The large proportion in the last decade is due, not so much to increase of scholarly ambition among the alumnæ of Vassar as to the fact that men's universities in America did not afford post-graduate study to women until the nineties. The first Ph.D. received from a great university by a Vassar woman came from Yale in 1894. The two women in the first decade who are Ph.D.'s did not attain that degree till about twenty years after graduation.

Next to imparting and acquiring knowledge from the teacher's desk the greatest desire among Vassar women appears to be to inform the public through the medium of printers' ink. The contributors to periodicals number 23 in the first decade, 25 in the second and 31 in the third, a total of 79. The writers of miscellaneous publications are 6, 20 and 22 for their respective decades, a total of 48; and the authors are five, four and five for the same periods, a total of 14. The combined lists make 141, or 10.83 per cent. of the whole number of graduates. In this entire register there is no name that would be instantly recognized by the general public, but the publications in the mass represent a very considerable amount of creditable and successful work. The periodicals to which so many contribute include journals of various rank. There is no important magazine or paper in this country, popular, literary, critical, political, scientific or religious, except possibly some technical journal of very limited scope, which does not number Vassar women among its contributors. Their names have appeared in some foreign periodicals as well.

In the next department surprise may be expressed at the lack of quantity. It seems strange that the medical profession does not attract more college women. As medicine is the only one of the so-called learned professions which women have entered in considerable numbers, and as it is a most honorable and lucrative one, it would be expected to appeal strongly to women graduates who are looking for a career. The only explanation seems to be that women who are attracted toward the healing art may not have the time and money for a preliminary college course. As the medical schools are constantly raising their requirements, this condition will probably be changed in time.

In the first decade twelve Vassar women have taken the degree of M.D., two of them at foreign universities. Of these nine are registered as physicians. In the second decade fourteen graduates have taken the degree of M.D., two at foreign universities. Of these twelve are registered as physicians. In the third decade there are so far twelve M.D.'s, ten of whom are announced as physicians, one being a missionary physician to China. There is also one medical student.

The total number of those taking a medical degree is 38, or a little less than three per cent. of the whole number of graduates. The num-

ber of practising physicians is 31, or about one for each class. This number is, however, quite irregularly distributed, the classes of '77 and '93 having four and some others two each. As there are twelve M.D.'s in the first and in the third decades, while the number of graduates in the latter decade is almost double that in the former, it would seem at first sight as if the rate of those studying medicine must be steadily declining. It is hardly probable, however, that such is the case, for the third decade contains so many who have recently graduated that it is of little value for statistical purposes.

The literary writers have already been mentioned. A few alumnæ have done good work as writers of text-books or of scientific papers. There are fifteen writers of text-books, eleven in the first, and two each in the second and third decades. The fact that nearly three fourths of the writers belong to the first decade seems to show that it requires considerable experience as well as maturity of mind to write a text-book. This apparently does not hold when it comes to publishing scientific papers; researches are quite as likely to be conducted by recent graduates.

There are four writers of scientific papers in the first decade and their subjects are astronomy, logic and mathematics, chemistry and mineralogy, wasps and spiders. There is one writer in the second decade (biology) and five in the third decade—two writers on astronomy and three on what the present writer fondly believes are biological subjects, but is not sure. For instance, 'Dinophilus Gardineri'; is it a mastodon or a microbe?

It was hoped by considering the miscellaneous occupations in decades to discover some tendency of the times, some drift of educated women toward new work, but this is observable in but two or three instances. Though there are many more kinds of work registered in the third decade than in the first, there are some occupations in the first decade that are not filled in the others, showing that much depends upon the individual. Again, women of the first decade often entered into modern pursuits in middle life. Thus library work, which has only recently become a profession, has drawn graduates of all ages.

In the list of librarians, cataloguers and assistants there are five in the first decade, four in the second, eight in the third. There is also a student in a library school from the first decade and two students from the third decade. Among the 17 already in library work several hold or have held positions in colleges, Columbia, Vassar, Wellesley, Bryn Mawr and Bates. Most of the librarians are of comparatively recent training, but in the first and second decades the work has often been undertaken after years of teaching. In the third decade it is usually begun immediately upon graduation, showing that as a possible profession library work is assuming increased importance in the eyes of the undergraduates.

The two occupations in which the increase of recent graduates is most noticeable are secretarial or clerical and philanthropic, notably college settlement, work. Of the 18 secretaries, there are three in the first decade, three in the second and 12 in the third decade. Several of these hold positions in colleges. Philanthropic work as a profession belongs wholly to the second and third decades. In the second decade are four graduates: three missionaries, two to Japan and one to India, and a Salvation Army worker; in the third decade are eight: five settlement workers, including one head resident; one missionary to China, one district agent of organized charities and one assistant secretary, State Charities Aid Association, making twelve in all. This list includes those only who seem to be devoting their whole time to the work; hence many holding prominent offices in the Women's Christian Temperance Union and various missionary organizations are not mentioned.

Under the somewhat liberal term of executive work are grouped three members of the first and three members of the second decade, though the members of the first might almost be classed in the philanthropic list. They are the matron of a reformatory home, the manager of a children's home and the secretary of a Young Women's Christian Association. In the second decade are an assistant to the lady principal of Vassar, a bursar of Barnard College and a worker at Pratt Institute.

Music and art have attracted eight graduates each. The artists are four in the first, and two in each of the other decades. Some of these have attained more than local note. The musical people are thus divided: In the first decade are two organists; in the second, an organist, a concert pianist, a professional singer and an assistant supervisor of music, New York schools; in the third decade are an organist and a professional accompanist; making eight in all.

It may surprise some readers to know that eight of the graduates have engaged in agricultural operations. In the first decade two are registered as farmers, a third as a dairy farmer and a fourth as manager of the Kingwood herd for the making of sterilized milk; there is also a fruit grower. In the second decade are a stock farmer and an orange grower. In the third decade is a rose grower. Let us hope that these educated women may wrest wealth as well as health from their contact with the soil.

Five graduates have engaged in business, three in the second and two in the third decade. In the second decade two are managers of manufacturing concerns and one is in the lumber business. In the last decade one has been business manager of a newspaper and is treasurer of a publishing company and one is in the jewelry business.

Vassar has always had a decided leaning toward astronomy, due

probably to the influence of Maria Mitchell, who for nearly a quarter of a century made the college observatory her throne room, whence her magnetic personality radiated far and wide. Here was trained her able successor, Professor Mary W. Whitney, '68. Besides those teaching astronomy, who are included in the general list of teachers, and those who have published astronomical papers, four have engaged in other forms of astronomical work. In the second decade one has been a computer at the Yale observatory; in the third decade are three, a lecturer, for six years worker at the Harvard observatory, a computer at the Yale observatory and a computer on the Nautical Almanac.

No Vassar woman has yet been ordained a minister, but the legal profession is beginning to attract a few graduates. There are three in the third decade. A member of '88 has taken the degrees of LL.B. and LL.M., was admitted to the New York state bar in 1895, and is registered as a lawyer. She is also married and has two children, but her marriage occurred previous to her legal studies and soon after graduation from Vassar. A member of '89 was admitted to the Illinois bar by examination in 1896, and was thereupon married. She has one child. She is not registered in the catalogue as a lawyer, but she has published the 'Municipal Code of Macomb, Ill., Revised and Codified.' A member of '95 is registered as a clerk and student in a law office in Chicago. Besides these three, two Vassar women have acquired the degree of LL.B., evidently for the purpose of general culture and not for legal practice. In 1887 the honorary degree of LL.D. was conferred upon Mrs. Christine Ladd Franklin of '69 in recognition of her attainments in mathematics and logic.

We now come to the twos and ones. In the first decade are two bookkeepers; in the second decade, two lecturers; in the third decade, two regents' examiners for the state of New York. A chemist is catalogued in the first and in the third decade, and a water analyst for the Massachusetts State Board of Health in the second. Two graduates have undertaken nursing, one in the second decade becoming a trained nurse; and one, Miss Reubena H. Walworth, '96, acting as a volunteer nurse in the Spanish War, dying in the service of her country. In the second decade are a draughtsman, a government clerk and a life insurance agent; and in the third decade are a translator from the French, an actress, a kindergartner, a canvasser, a director of a gymnasium, a director of a domestic science department, and a promising student of chemistry who has been an assistant, lecturer and docent at the University of Geneva, Switzerland.

An unusual record is that of a member of '83, a young woman of brilliant literary gifts, who chose the life of a Salvation Army worker. After laboring for twelve years amid the slums of London and attaining the rank of Major, she became converted to the Roman Catholic

faith, returned to New York, and in 1900 entered the novitiate of the Dominican Sisters at Albany. Another individual career is that of Miss Stematz Yamakawa, '82, the only Japanese girl ever graduated from a college. Upon her return to her native land she married the Marquis Iwao Oyama, a field marshal commanding the second army of the empire. Closely associated with the Empress, and the only Japanese woman of rank familiar with occidental civilization, she has had a wide social and educational influence in her native land.

The amount of club, philanthropic and general educational work done by the graduates of Vassar has never been computed. As members of school boards, trustees of various colleges, organizers and directors of important societies, officers of charitable institutions, their influence has been felt in every part of the land. Happily, work of this kind by educated women is now so common as to call for little comment. If the college has as yet produced no famous genius, it has sent forth more than 2,000 daughters (2,332 in 1904) with well-trained minds, accompanied in most instances by sound bodies, who have quietly and gradually helped to raise the status of women wherever the English language is spoken or read.

DEXTRALITY AND SINISTRALITY.

By Dr. GEORGE M. GOULD,
PHILADELPHIA.

THE theories that have been advanced as to the origin of dextrality and sinistrality are:

1. A natural provision. (Sir Charles Bell, and others.)

2. The left-sided location of the heart. (Referred to by Wilson.)

3. A greater supply of nerve force to the muscles because of an earlier and greater development of the brain upon one side. (Professor Gratiolet.)

4. Obstruction to the flow of blood in the vena cava, by the pulsation of the aorta. (Dr. Barclay.)

5. Inspiration produces, mechanically, a superior efficacy of the muscles of the right side. (Professor Buchannan.) This theory is based upon the observation of the anatomic peculiarities of the liver, lungs, etc., and their supposed influence upon the center of gravity of the body. (So far as pertains to the center of gravity, the theory has been adopted by Dr. Struthers and by Dr. Allis.)

6. The center of gravity theory. The influence of the weight of the viscera of the two sides of the body, upon the position of the center of gravity. (Dr. Struthers, accepted by Buchanan, Allis, etc.)

7. The origin of the subclavian arteries, the left before the right in the left-handed, with superiority of blood-supply to certain structures. (Professor Hyrtl.)

8. The development of one cerebral hemisphere more than the other. (Wilson.)

9. The Topsy theory—'just growed.'

These theories merit little argument in rebuttal. No. 3 and No. 8 are essentially the same, and, of course, are mere avoidances of an explanation. No. 2, No. 4, No. 5, No. 6 and No. 7 are not based upon facts, and contain fallacies of observation, rendering them at least of insufficient reach and validity. No. 9 is almost as good as any or all of the rest, and we are left with the frank confession of Dr. Struthers, that the mystery 'has baffled satisfactory explanation.' Carlyle said it was 'a question not to be settled, not worth asking except as a kind of riddle.' It is, however, of great and practical importance in medicine and in social life.

In a large way and notwithstanding a certain number of exceptions, it is an illuminating truth of biology that 'the ontogeny repeats the

phylogeny.' We can, therefore, never explain the phases of development through which an organism passes except by knowing the corresponding stages of evolution of the line of its ancestral forms. If, therefore, we ever solve the mystery of dextrality and sinistrality, it will be by the study of the conditions, habits, necessities, etc., of the ancestral types when dextrality and sinistrality arose. The infant of a few months shows no signs of preference in the use of the hands; it is not yet dextromanual, nor ambidextral; it is simply nondextrous, or ambisinistrous. Almost as soon as it exhibits any conscious effort toward skillful use of the hands it begins to show signs of dextromanuality. Before it walks, before it is one year old, dextrality is clearly pronounced. Baldwin (Pop. Sci. Mo., Vol. XLIV.) has demonstrated experimentally that it is plainly established as early as the seventh or eighth month. The period in phylogenous savage life to which this of the infant corresponds must, therefore, be that of the earliest phase of humanization. The animals, even the anthropoid apes, do not, so far as I have observed, exhibit it. Vierordt says that parrots grasp food with the left foot, by preference, and that lions strike with the left paw. Livingston is quoted as thinking 'all animals are left-handed.' I suspect this is all error, because, as a rule, it would disadvantage rather than help in the animalian struggle.*

Since any sort of consciousness of the facts has existed the wisdom of dextromanuality has been emphatically exhibited: (1) In the word *dexterity*, which is the prized and honored quality of savage and civil-

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* In the comparative absence of interest in these subjects there is a resultant dearth and awkwardness of words describing the conditions. It seems necessary to coin a few in order at least to avoid more cacophanous ones. The following, some of them already listed in the dictionaries, may be found useful in future discussions:

Dextral, pertaining to the right side of the body.

Sinistral, pertaining to the left side.

Dextrality, *Sinistrality*, the corresponding abstract qualities.

Dextrad, *Sinistrad*, toward the right, or left, respectively.

Dextromanual, *Sinistromanual*, dextrality and sinistrality, respectively, as relating to the hands.

Dextropedal, *Sinistropedal*, as relating to the feet.

Dextrocular, *Sinistrocular*, as relating to the eyes.

Dextraural, *Sinistraural*, as relating to the ears.

Dextrocardial, *Sinistrocardial*, as relating to the heart.

Dextrohepatal, *Dextrosplenic*, etc., may be formed.

Dextrocerebral, located in the right cerebral hemisphere.

Sinistrocerebral, located in the left cerebral hemisphere.

Dextrorse, turned, turning, or moving to the right.

Sinistrorse, turned, turning or moving to the left.

Sinistrous, awkward, unskilled.

Dextrous, skilled, expert.

Ambidextrous, equally skilled with both hands.

ized man; (2) in the secondary meaning of the word *sinister*—unlucky, ill-omened, evil; (3) in the persistent training of all left-handed children, by parents, teachers, etc., to make them like the rest of the right-handed world. These three facts, the residue of the psychologic habits of ages, persistent in all history, crystallized and embedded in the very language itself which chronicles all mentality, help to give us the clue to the solution of the riddle.

Skillfulness, 'handiness,' expertness of sense and act, were the sole means whereby the savage could win his place in the world, domesticate animals, conquer in all sorts of conflicts, supply himself with food, clothing, house, etc. It was necessary that one hand should be chosen to do the dextrous or more skilled tasks, for the simple reason that exercise develops and perfects function, and one would learn to be more skilled and 'handy' with one hand than with both. The savage required no treatise on logic nor even any conscious reasoning to teach him this primary lesson. His food and life depended upon his learning it.

But that it was an acquirement, that the law and necessity were not exceptionless, that it was due to no absolute fatalism of anatomy or physiology, is evident from the fact that so large a proportion of left-handed children and adults exist in all races and times. The education of left-handed children, whereby their writing center, naturally dextrocerebral, is by forced training and long habit transferred to the left cerebral hemisphere, is another demonstration that no inherent neurologic or psychologic law governs the location of the cerebral center or its peripheral outworking. When the occasions arose in the humanization process, and the demand for the differentiation of cerebral mechanisms was made, the plastic brain on either side could take up the work. And pure, or untrained, left-handed persons are to-day as expert as their right-handed fellows. All that is needed to explain dextrality in 98 per cent. of children is some ancestral savage custom, habit, or necessity, widely prevalent, which inclined to the use of the right hand and eye for one or two exceptionally intellectual tasks. The inheritance of aptitude, the force of custom, and the necessities of the struggle for existence would certainly fix the persistence of dextrality.

We must not forget that the somewhat sudden and clear preference of dextrality and sinistrality of the child of to-day was in the far-away ancestral line spread out over long periods of time. A year or two of the child's life represents thousands of years of slow acquirement and habit.

Again, it should be remembered that even in our preferences and habits it is only in a few things that one hand, etc., has the greater expertness, accuracy and rapidity. It is often rather a division of

functions, a differentiation of ability, than a unique one. In the dextral the left hand does many tasks of as great or greater importance, and with equal or superior skill, as the right. In eating, the fork is now more used than the knife; in gunning, the left hand is given the vastly more important, difficult and onerous task; in chopping, hoeing, shoveling, picking, lathe-work, railway locomotive engineering and other tasks the left arm and hand often execute the chief and more expert tasks. Especially noteworthy is the playing of the violin, 'cello and bass viol. The 'fingering' is done with the left hand, and forms a striking reversal of dextrality, because it is by all odds the function requiring more manipulative skill, accuracy and rapidity. I do not know that the fact itself has ever been observed and stated, but certainly the reason of this strange contradictory practise has hitherto escaped the attention. It is, I think, due to dextrocularity. With few and easily explained exceptions dextromanuality is a result, or a concomitant, of dextrocularity. If the violin, 'cello and viol were fingered with the right hand the learner would be greatly handicapped by the foreshortening which would exist as his dextral eye glanced along the neck of the instrument straight in front or below this eye. The learner must see his fingers and gain precision in placing them by careful visual estimates. But when placed sinistrad the right eye sees the neck of these instruments and the fingers at an angle which permits more accurate observation, estimates of distances, etc., than would be possible if the instrument were fingered with the right hand. In those instruments necessarily held in the median line, some wind-instruments, the flageolet, hautboy, etc., the right hand asserts its selective and more difficult task. When the hands are not seen at all, as in the flute, fife, etc., the right again has its choice. No pupil with sinistromanuality established can learn piano-playing easily. I know of one who was a great lover of music who failed utterly after long perseverance.

There are other cautions to be emphasized relating to the acquirement of dextrality by the savage: Nearly all the actions which we now call right-handed were in primeval times to him unknown. This is especially true of three things. Knives and forks have only been used in eating for a few hundred years. He ate with his fingers, and one may suspect he used the left as much as the right in this way. The Mussulman custom and its reason are, of course, both modern. Secondly, the modern gun and revolver had not been devised. The bow and arrow, the spear, boomerang, club, etc., could be used as well with the left hand by the sinistromanual. Thirdly, writing was unknown, or relatively so, and, as we have now learned, that locates the speech center in the cerebral hemisphere opposite the writing hand. It is thus evident that dextrality in the savage, at the time when it

began to become habitual, must have been at best only partial, incomplete, and for a very few acts. The left-handed arrow-chippers, basket-weavers, club-wielders, sewing-women, etc., even if more numerous relatively than in civilized life, would perhaps attract little or at least less attention than now, and would be less discouraged, surely less taught to reverse the natural inclination.

In default of systematic banding and military training, also, the left-handed spearmen, bowmen, swordsmen and clubmen might not have much attention directed to themselves and sometimes might have an advantage over their single and dextral adversaries, *e. g.*, in tilting. The preference in heraldry for dextral quarterings, etc., is by no means uniform.

But there was one overlooked factor which was doubtless decisive in setting up the trend toward dextrality. This was the development of sign-language synchronously, and even preceding that of spoken language. The ineffaceable relics of this long and arduous period exist in present day language, plainly in many savage tribes and customs, but the most striking proof is displayed in our so-called Roman numerals. The fingers of the hand held up, or counted off, were beyond question the beginnings of arithmetic, the means of barter, the method of stating the fundamental fact of number requisite in all thinking and doing. Military and intertribal dealings, especially made the custom powerful and even sacred. One finger was the origin of our figure *one,* the second equaling *two,* etc., up to five, or V, which fork was made by the thumb stuck up opposite the first I. When the counting was more than five, the other hand was made to represent the first five, the digits being added up to ten, when two forks were used, or the crossed thumbs, which constituted X., or ten.* The impressive ceremonies of warring and bartering tribes would stamp with distinctive approval the hand used in the sign-language, and henceforth it would become the honored one, the stamping and writing hand, and in time the sword-hand. The right was chosen as the sign and numbering hand because the left was naturally used for the highly important task of guarding the sinistrally-placed heart with the shield. War is the substance of all early history and of the savage aeons which preceded all history. Dr. Flint (*The Sun,* April 17, 1904) says that deaf-mutes may have an aphasia that prevents the use of the right hand in the sign-language.

Speech is the sole example of the higher functions, sensational or motor, which is single. Feet, legs, arms, hands, vision, hearing, all

* It does not matter with which hand the first numbering, in some cases, was done; the intelligent attention must have been directer to the action with the dextral or spear side. Homer and the earliest Greek vases show the right was *ἐπὶ δόρυ*, the spear side, and *ἐπ' ἀσπίδα* the shield side.

are dual in nature, requiring dual centers of coordination and innervation in the two halves of the brain. But speech, being a single function, can have but one center, and that, of course, must be located, not in any median place, because there is no such place, but in one or the other side. We also know by physiology and pathology that in the dextral it is in the third left frontal convolution, and in the sinistral it is in the corresponding position on the right side. We know, furthermore, that it is the intellectual act of writing, rather than the grosser acts and functions, which localizes the speech center. A man may be left-handed for everything but writing and the judgments issuing in the correlations of spoken words are formed and innervated from Broca's convolution. Or *vice versa* in the case of the sinistromanual writer who is dextromanual for all other acts.

The reason why dextromanuality, dextrocularity, etc., must coexist with sinistrocerebrality becomes manifest. The function of speech or writing is the method whereby judgment or volition passes into action. The initial, dominating and guiding motility to vocal organs, to hand, and even to foot, springing from closely contiguous, and hence more quickly and accurately acting, cerebral centers, will be better correlated and certain than if the centers were in opposite cerebral hemispheres. The indicator of all action, the very creator of intellect, is vision. Hence all right-handed people are also right-eyed.* The centers for right vision, right motion, and for speech are thus in close relationship and upon the same side of the brain. As I have said (*Science,* April 8, 1904):

> The unification and perfection of innervation and cerebration must be better if initiated and executed with the cerebral centers mainly upon one side of the brain, than if the unity is gained by means of the longer and more distant commissural fibers extending between the two sides of the brain. In the right-handed the speech center is in the left side of the brain, as is also the motor center for the right hand, and the optical center of the right eye. The dependence of all motion upon a perfect correlation of vision and judgment needs only to be mentioned. That all intellect is psychologically the product of vision is less recognized, but is not less absolute truth. The right hand writes, possibly because the right eye looks down upon the writing more accurately than would the left; both depend upon the synchronous and

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* One of the best tests of predominant dextrality or sinistrality is the 'sighting' of a stick to see if it is straight, or the sighting of a gun or pistol. Dextrocularity is largely a dictator of general dextrality. And of dextropedality also, for the dextral is right-footed also. Errors of judgment, however, have been frequent as to the function of the feet. The 'spade-foot' is the left, naturally, because the right leg and foot are the directing ones, in the dextral, who also, as the masonic ritual directs, steps off with the left foot first. The dextral must spring from the right foot. It has been said that the oblique line of the body of the dog in trotting is due to incipient right or left-footedness. But all soft-footed animals avoid 'interfering' by this obliquity of progression. The much discussed knockout blow of the pugilist with the left is, I suspect, because of the better spring from the firmer right foot.

closely interrelated guidance of the speech-making function. All three are in closer unity and contiguity than if either were in the opposite side of the skull.

This furnishes the physiologic reason why all attempts at ambidexterity are failures, and unwise.

The chief centers most closely interrelated in writing and thinking are thus demonstrably better harmonized when in one side of the brain. The mechanics of neurology are plainly less difficult than could be achieved by any foolish and unsuccessful ambidexterity. I have never seen anything but bad results from the attempt to train children to use the right hand instead of the left, when there is a decided tendency or habit to be left-handed. Moreover the attempt is never successful. The best consequences are poor, and are only awkward mixtures of the two forms, which yield confusions and indecisions during the entire subsequent life. I could cite many instances in proof, some of them most pathetic, in which disease and life-failure resulted. One that plainly illustrated the neurologic troubles was that of a naturally left-handed friend, A. V. P., who by arduous and continuous training during his childhood was compelled to write with his right hand. For all other acts he is left-handed, but he can not use his left hand for writing. Although now past fifty he has always hated any writing, the mere act of doing so, and he can not do any original thinking while writing. He is for this purpose compelled to rely on a stenographer, and then his ideas flow freely and rapidly. If he tries to think, plan, or devise and to write at the same time there is a positive inhibition of thought and he must make sketches, epitomes, several efforts, copyings, etc., in a painful and most unsatisfactory manner. The attempt at ambidexterity has been a lifelong obstacle to him in his professional progress. The ambidexterity of surgeons, artists, etc., is overpraised, exaggerated, and fallacious. It is of course advisable in exceptional callings and actions to cultivate skill in the more awkward hand, but that is a very different matter from 'ambidexterity.'

All agree that perfect ambidexterity has never existed, despite all training. It is neither possible nor desirable.* Sinistrality is no defect and of no disadvantage. That said to exist in criminals, idiots, etc., like many things 'Lombrosal,' is not true, or it is *post hoc,* etc.

It seems that there is an 'Ambidextral Culture Society' in England which, in default of something to do of use and in accord with nature's indications, wishes to insure that every child at school shall be so drilled in both separate and simultaneous use of the two hands that he shall have the two equally strong, sensitive and skillful. The pitiable victims! The organization might better call itself the society for nullifying the law of the differentiation of function necessary to all progress, for returning to barbarism in the handicrafts, and for lifelong cruelty to the left-handed.

The essential and clarifying thought of the foregoing explanation is that as the writing act now locates the speech-center, although all other acts may be opposite-handed, so the right-hand sign-language and numbering would necessarily have had the same effect in barbarous

* See the case of Morse, reported by Wilson; especially his own, and that cited on p. 146.

times. That this sign-language of primitive man was dextral is not to be questioned, as about 98 per cent. of babies are now clearly right-handed before they are one year old. The protection of the heart by the shield would constitute sufficient reason for the institution of dextrality in counting and sign-making, and custom and uniformity of habit especially in early times, would result in almost a universality. But not an absolute one, for one or two per cent. are now sinistral. And the Bible story of the Benjamite tribe illustrates how the habit would not be absolute. There is in all this one noteworthy neurologic fact: In view of the long continuance and vast preponderance of dextrality it seems strange that the brain preserves all the preformed mechanisms, plastic and ready to make a sinistral child, and the outworking of sinistrality is as prompt, the result as dextrous, as if dextrality had been chosen. The wonder at this is, however, lessened when one notes that all the functions of completed dextrality are at the same time and in the same person now possible to the sinistral; there is a mere difference in the degree not in the kind of expertness. Besides this a number of left-handed acts in the dextral, *e. g.*, those of the violinist, gunner, etc., are far more expertly and finely coordinated than those of the right, etc.*

If the foregoing explanation of the origin and perpetuation of dextrality is adequate, it remains to explain the origin of sinistrality. Why are there about two out of a hundred naturally left-eyed and left-handed? Fundamentally, of course, because the speech-center is located in the right cerebral hemisphere, and the contributing and executing centers of vision and motion act in better unity if they are in close connection and contiguity than if connected by long commissural fibers to and from the opposite sides of the brain. The dextrocerebrality of two per cent. of sinistral exceptions to the usual law appears explainable, perhaps in part by persistence of original sinistral types, but more certainly they are due to accident, injury, disease, etc., of dextral organs, in the young of our ancestors. Especially in savage life would these accidents be more numerous than now. The loss of even one dextral finger might compel the education of the undeveloped speech center on the right side. Injury to the right hand and arm, even of the right foot or leg would do the same. Deafness of the right ear would compel a turning of the left ear forward and might work out complete sinistrality. But more important than all these causes combined would be the more frequent greater ametropia, amblyopia, dis-

* There is thus no danger and no need of a greater weight of the half brain initiating dextrality in the dextral, and all the discussion and labor of comparative weighing the two halves is relatively useless. Moreover the cerebral mechanisms must be equally perfect even if not equally exercised. Taken in the average the two sets of organs, central and peripheral, do about the same amount of work.

ease, leukoma, etc., of the right eye, compelling the use of the left, and thus transferring all centers of dextrousness to the right side. I have repeatedly demonstrated the persistence of dextrocularity even with visual acuteness considerably less than that of the left. But there is a limit to this 'accommodation,' and if the amblyopia of the right is greater than double that of the left, the patient becomes left-eyed. In savage and in semicivilized life these accidents, diseases, ametropias, heterophorias and strabismuses of the right eye would again be far more numerous than in our day and civilized peoples. Our two per cent. of sinistral children seem for the greater part to be the descendants, by the laws of heredity, of ancestors who in childhood and youth have been compelled to become sinistral by the causes enumerated.

Is it possible that there are proportionally more left-handed among oriental nations who read from right to left, than in those who read from left to right? A writer in the *Cornhill Magazine* (1889) says that the change in writing whereby the proceeding from right to left was reversed was due to the use of ink and pigments in writing, and the avoidance of smearing the fresh-writing by tracing the letters from left to right. But individual writers would not do this, and, if they did, they could not get their writing accepted! It is difficult to see how there would be less smudge and smear by the reversal.*

The arguments for upright writing are incontestably strengthened by some facts I have lately discovered as to the frequent influence of an axis of astigmatism in the dominant eye varying by about 15° from 90°, in producing a habitual canting or sideways inclination of the head. This habitual cant of the head is often followed by spinal curvature. Probably most spinal curvatures are produced in this way, and the number of cases is much greater than is supposed. Such a patient can see upright lines, which predominate over all others in civilized life, especially in those who read much, only by holding the head to one side. When the axis of astigmatism is about 75° the head must be canted to the right to see plainly. When it is 105° it must be canted to the left. Slanted handwriting is itself pathologic, or produces pathologic results of many kinds. The printed letters of the alphabet should be refashioned to avoid all lines except the vertical and horizontal. This would greatly conduce to lessening of ocular and neurologic labor, and would increase ease and celerity of reading.

* This writer says that artists paint from left to right, that the spectator views the paintings of a real landscape in the same way, etc. Even corkscrews, buckles, buttons on clothing—men's, he says, not women's—are for the right-handed, and asks, *why?* The figures on the faces of our clocks and watches are traced to the same cause; but he forgot that the clock face is the modified sun-dial made round, the location of the shadow of the meridional instant line, dictating the placing of the figure 12, and of all the related ones of the day.

Almost the only letters that could not be thus remodeled and bettered are *V*, *Z*, *X*, which are little used. *K* and *R* also require some slanted strokes. The others could all be made up of vertical and horizontal lines. The vast majority of astigmatisms cluster about axes 90° or 180°, and those which are anomalous and unsymmetric produce disease unless corrected, as they may be by proper spectacles.

The summary of the foregoing theory of the origin of dextrality and sinistrality is:

Modern pathology has demonstrated that the intellectual acts of writing and reading locate the speech center upon the cerebral side opposite the writing hand.

The centers for vision, audition, and motion of the hand and foot for correlated dextral or sinistral actions and sensations, are in the same side of the brain.

Coordination of sensation, perception, judgment and act are rendered more accurate, expert and quick by this close contiguity and inter-relationship than if made by commissural fibers from the other cerebral hemisphere.

The original location of the speech center in the dextral was caused by the almost universal employment of the right or spear-hand in sign-language preferred to the left or shield-hand, because this was more restricted in movement by holding the shield over the heart.

The origin of left-handedness was in large measure due to the location or education of the speech center in the right brain because of injury to dextral organs, but chiefly to disease or deficient vision of the right eye.

Ambidexterity of any general or thoroughgoing kind is neither possible nor desirable, and the attempt to bring it about results in suffering and disease.

Vertical handwriting, and printed letters made up of vertical and horizontal lines, should be encouraged.

THE LAKES OF NEW ZEALAND.*

BY KEITH LUCAS.

IT is difficult to make general statements which will sum up any points in the morphology of the lakes of New Zealand. This difficulty arises in the main from the strange heterogeneity of the lake-basins. It would be hard, for example, to find any points of resemblance between two lakes such as Taupo and Wakatipu. In the latter the lake-basin seems to be an integral part of the surrounding country; its slopes continue the slopes of the mountain-sides. It is a mountain valley filled with water, and if it were drained dry it would scarcely appear in any way remarkable. Contrast with this the basin of Taupo. It is a trough abruptly sunk in a country which seems wholly unprepared to receive it. The perpendicular cliffs which form its western shore drop suddenly down from among hills whose slopes are comparatively gentle; in one place the cliff even forms a clean section through a large hill, cutting it from base to summit with a perpendicular face over 1,000 feet in height.

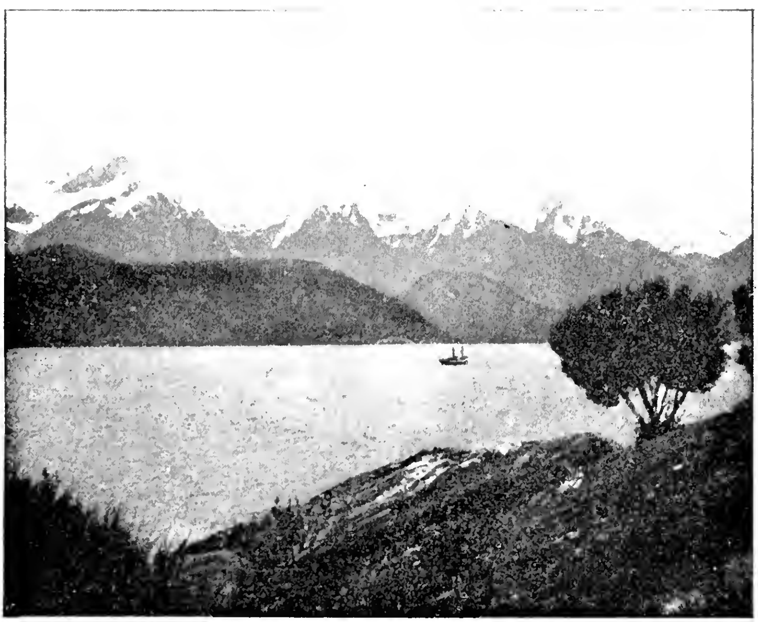
In their relations to the surrounding country, Manapouri may be classed with Wakatipu, and Rotoiti with Taupo. In the former group there is a correspondence between the position of the deepest water and the gradient of the land in the immediate nighborhood; in the latter group no such relations can be traced. In Wakatipu the greatest heights combined with the steepest gradients are those of the Remarkables and Cecil peak, and between these the deepest water lies. In Manapouri the same conditions are fulfilled by the Cathedral peaks and Cone peak. The existence of this relation indicates a rough correspondence in type between these two southern lakes and such familiar types as the lakes of the English Lake District.

A further point of similarity between Wakatipu and Manapouri is the presence in each of a large flat area where the water is deepest. This peculiarity of form is not to be confused with the tank-like form of Taupo. In the former, sloping sides lead down to a level floor, which marks the limit of depth; in the latter, perpendicular sides lead to a level floor, beyond which there is a further slope to the deepest point.

In Lake Taupo, the steepest gradient leading to the highest point is found at Karangahape, on the western shore, but the deepest water lies in the northeast part of the lake. In Rotoiti there is a similar

* Conclusion of an article in the *Geographical Magazine* for June.

Walter Peak, and part of Cecil Peak (on the extreme left), seen from Queenstown Bay, Lake Wakatipu.

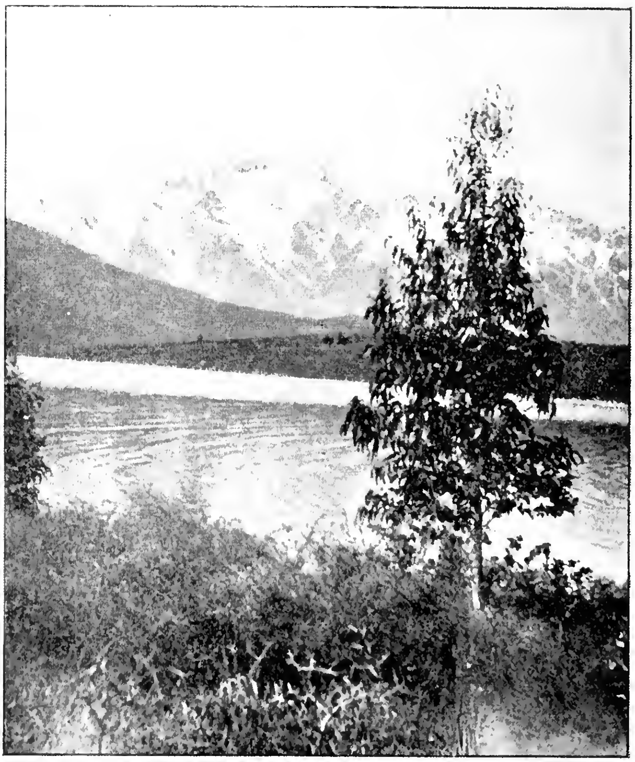


Lake Manapouri, looking north-west from the mouth of Hope Arm. Pomona Island is seen on the left, and beyond it lie the Cathedral Peaks.

lack of correspondence between Matawhara, at the east end of the lake, and the deep water which lies some distance to the west of it.

The two lakes Taupo and Rotoiti have in common a tank-like form of basin. It is also possible that a relation between the two may be indicated by the presence in each of isolated banks or shoals. Examples of such shoals are found in the west end of Rotoiti, and in Taupo between Karangahape and the island Motutaiko.

The remaining lakes form a very heterogeneous lot. Rotorua is a saucer-like depression, a mere continuation of the whole catchment basin in which it lies, regular in its outline and in its subaqueous slopes. It can not be compared to the more abrupt and tank-like lakes among which it lies, though it may possibly have with them a common origin in subsidence, similar but less violent.



THE REMARKABLES, LAKE WAKATIPU. IN THE FOREGROUND IS SEEN THE FRANKTON ARM.

Waikare and Whangape are so shallow as to rank rather with swamps than with lakes, in spite of their considerable area. The interest of the former lies chiefly in its peculiar relation to the Waikato river, a relation which enables it to reduce the harmful effects of floods, though not lying on the river's actual course.

SHORTER ARTICLES AND DISCUSSION.

CHARACTERISTIC CURVES OF COMPOSITION.

In the June number of this journal there appeared an interesting article by Dr. Robert E. Moritz, on 'The Significance of Characteristic Curves of Composition,' mostly devoted to an examination and criticism of some conclusions stated by me in a paper published nearly twenty years ago and practically applied in another paper published in 1901. To those who have had enough interest in this somewhat curious application of the doctrine of chance to read all of these papers carefully no comment upon or reply to the criticism of Dr. Moritz need be addressed, but in these piping times everybody is so busy preparing his own papers for the press that he has time only to glance at the results of the intellectual activity of others, and it has become a common, indeed, almost necessary habit to make a hurried hunt for the conclusions of scientific investigations of a subject a little out of one's own field and to accept them when found for lack of time to do otherwise. For this reason I will invite attention to one or two facts having an important bearing upon the question at issue.

The assumption of Dr. Moritz is that the form of what I have called the characteristic curve of a composition, plotted as first described twenty years ago, will depend more on what he calls the *form* of composition (character, as to subject matter, etc.) than upon any personal peculiarities of the author. He believes this, the *form* of composition, 'to be the predominating factor overshadowing all others' and that 'conclusions regarding the authorship of spurious or disputed writings based upon a comparison of the word curves of work differing either in form of composition or in other essential respects must be considered worthless.' After (not before) making these and other equally sweeping assertions, he sets forth the evidence by which he believes they are supported. The principal part of this evidence is an exhibition of results of a series of 'word-countings' of various authors which he has made, from which results he deduces the conclusions quoted above.

Unfortunately these conclusions are of no value whatever because the observations on which they are founded are totally inadequate and, indeed, are specifically 'ruled out' in the very beginning by the author himself in a quotation from my earlier paper. In this it was declared that a count of '100,000 words would be necessary and sufficient to furnish the characteristic curve of a writer,' and yet, in the face of this statement, Dr. Moritz proceeds to make his sweeping deductions from groups including 1,000, 5,000 (generally) and in the case of one author two groups of 15,000 words each! He puts the curves of the two latter, including only 30,000 words in all, by the side of the Bacon-Shakespeare diagram which includes 600,000 words (not less than 100,000 being 'necessary') and then makes the charming comment upon the latter that, 'instead of furnishing a convincing proof or even contributory evidence, leaves the problem of disputed authorship wholly untouched!' In this case the value of the evidence depends on some power higher than the first of the number of words, but even if directly proportional it would be twenty in favor to one against, and it is difficult to believe the author serious in condemning so positively and confidently the evidence of a 'characteristic curve'

when he is so very, very far from ever having made one. But serious he seems to have been and perhaps never more so than when he declares that the 'average word length alone . . . would, in general, be indicative of the nature of the curve.' This is equivalent to saying that the form of a curve is known when its mean ordinate is known, and is a statement which, to those who are accustomed to the graphic representation of variables, will betray an almost immeasurable unfamiliarity with problems of this kind. Among other evidences of this state of mind which might be cited, the construction of a 'typical word-curve of extreme light dialogue'—from a count of 5,000 words from Swift's 'Polite Conversation'—is not the least convincing. To produce this Swift's curve is 'corrected' by the suppression of certain words of seven or eight letters, for no assigned or imaginable reason, except that perhaps Dr. Moritz thinks that Swift ought to have known better than to have used them. The curve of this expurgated edition of 5,000 words from Swift is interesting in form, but if it be the 'typical word-curve of extreme light dialogue' in the English language, as declared by Dr. Moritz, those who have dabbled, even a very little, in word-counting of modern comedy and humorous story writers will be saddened by the thought that the art of composing 'extreme light dialogue' must have long ago become extinct.

It seems impossible to avoid the conclusion that Dr. Moritz, perhaps as a result of a somewhat hasty examination of the subject, has failed to grasp in its entirety the fundamental principle on which the whole doctrine (if so dignified a term may be used) of 'characteristic curves of composition' is based, and a brief exposition of its most important propositions may not be out of place.

The notion that every author, however voluminous, must necessarily be restricted in his use of words to a vocabulary which would remain sensibly constant after his productive period had been reached, which, in its character and extent would be one of the personal 'qualities' of that author and thus offer a means of identification, is due, as is stated in the paper of twenty years ago, to Augustus De Morgan, who suggested that vocabularies might differ so much among different authors as to make it possible to differentiate them by means of the simple average number of letters in a word. In making some tests of this proposition it immediately became evident, as might have been anticipated, that vocabularies might differ indefinitely and enormously and at the same time agree in average word-length. The scheme for the graphic display of variations in the average frequency of occurrence of words of different lengths, as explained in the papers under discussion, was then devised and proved to be a vastly more powerful means of revealing peculiarities in composition. As to the value of this method of treatment, which is the one original feature of the whole, there seems to be no question, as even my critic has paid me the highest compliment in his power in making continued and apparently confiding use of it. The point at issue is, rather: Was De Morgan right in assuming that the personal element enters into the vocabulary of any author to such an extent as to furnish a means of identifying his writing? He evidently believes that it played so large a part as to determine the average length of words used; the theory of 'characteristic curves' implies that personality may determine *the way in which words are used* rather than their average length, and it furnishes a method for revealing peculiarities, *such as persist in the long run* (this is the kernel of the thing) in the relative frequencies of words of different numbers of letters, syllables, etc., of sentences of different lengths or of any 'qualities' that may be treated numerically. Because of simplicity, ease

of application and probable greater certainty of result, the element of word-length was that to which attention was first given. Besides, there is in this another important advantage which will be presently explained.

Now, in spite of an oft-quoted assertion to the contrary, words are used to express ideas, and the particular words used will depend largely, perhaps most largely, on the idea to be expressed; but they will also depend on the person to whom they are addressed; on the conditions under which they are spoken (as in private conversation, public address, etc.) or written (in correspondence, for publication in newspapers, journals or books); especially on the age or period in which their author lived; and perhaps on a thousand other things; but in any or in all of these cases they are determined *by the person who uses them.* The theory assumes that by combining a *sufficiently large number* of verbal expressions of any author, variations due to these thousand and one causes may be eliminated and that due to the personality of the author, the only one in fact which is common to them all, may stand revealed.

Moreover it is clear that in selecting from many personal idiosyncrasies of an author that which will best serve for purposes of identification, it will be wise to choose one *of which he is himself unconscious,* for this would most certainly persist and prevail in everything he wrote, never being either shunned or encouraged. While an author will often give thought to the arrangement of words and sentences and to other features of composition, he will almost never stop to consider the number of letters in the words which he uses, and, therefore, such personal peculiarity as may be shown by word length frequency curves is almost certain to be persistent.

Dr. Moritz is quite right in his belief that 'form of composition' (subject matter, etc.) affects very powerfully the form of a word-curve, seeming, at first, to conceal the element of personality, just as in the physical world local, near-at-hand causes seem in their effects to overshadow and conceal those of remote but more constant origin.

But it must never be forgotten that they only conceal, they do not destroy; they may over-shadow, but they can not obliterate. The position of a freely suspended magnetic needle does not, at first sight, appear to be in any way related to the phases of the moon, but a very long series of observations reveals this relation very clearly and certainly, although local happenings affect it to a much greater degree and apparently conceal the more persistent influence of a more remote cause. It is the constancy of this influence, the fact that it is present all the time, which makes it possible to differentiate it from others, often exceeding it in magnitude, but less regular in operation. And so it is *in the long run* that the personal peculiarities of an author, especially the unconscious peculiarities, will be revealed, and the so-called 'characteristic curve of composition' was suggested as a means of developing and displaying one of them.

The question under discussion includes, therefore, two parts: First, *does* the personality of an author enter into his composition so as to affect its purely mechanical aspect in a way of which he is quite unconscious?—and, second, does the 'characteristic curve' furnish a means of exhibiting such peculiarities of composition if they exist? It is not likely that anybody, after a little reflection and investigation, will be willing to say 'no!' to the first, although few people fully recognize how steadily and surely one is influenced by a bias of which one is totally unconscious. Although such unrecognized influences are often very feeble, their very persistency, the fact that they 'never sleep,' may give them so large a place in the final summing up of any series of operations that they determine the distinctive character-

istics of the operator and give 'personal quality' to the work itself. About twenty-five years ago, being much interested in problems of this kind (more than at the present moment), I spent many 'odd' and generally otherwise unusable quarter and half hours in pitching a stick into the air and noting whether it fell across any of a series of parallel lines drawn on a plane surface upon which it dropped. This cheerful occupation was continued until the stick had been thrown 20,000 times, and then the number of times it had fallen upon a line was compared with the number indicated by theory. It so happens that according to theory this experiment ought to determine the value of that important constant, the ratio of the circumference to the diameter of a circle, and in the present instance it promised for a time to do this in a most satisfactory manner. Indeed at the end of about 12,000 throws the value of 'π' was determined correctly to three decimal places and nearly correctly in the fourth. But from this time on the graphically constructed line of the experiment began to depart very slightly but very persistently from the line of theory and continued to do so to the end. The explanation was easy, it being evident that the operation which was intended to be purely mechanical was not so. There was present an unconscious personal element which interfered with the regularity of the work, to a very minute degree, it is true, but the effect of which became manifest when the *run was long*. The deviation was due to a, perhaps, very rarely occurring error of judgment in determining a single fact of the experiment, but in the long run these errors leaned towards one side, and this was beautifully revealed in the graphic exhibit of the whole series. I do not recommend the process as a means of determining errors of this kind, for it is altogether too laborious, and besides, I have not found it necessary, kind friends having generally kept me well informed as to my errors in judgment.

What I want to illustrate and emphasize is the importance of my being *unconscious* of this bias, which otherwise would have destroyed the value of the whole experiment. It is the 'unconscious touch' which most surely identifies personality in any artistic performance. It is likely that Raphael never meant to paint two Madonnas alike, indeed it is likely that he would generally make some effort to have each different from all that he had done before, but all have something in common, unsuspected by the artist but known to the expert and furnishing a practically sure means of identification. Moreover, these unconscious technicalities of an artist, the key to identification, are most frequently known and utilized by persons who have little knowledge and less appreciation of the real artistic qualities of the works which they compare (see Ruskin on the identification of old masters), the operation being the more certain as it is more purely mechanical. It is within the memory of most of those who will read this that the result of a national election together with the whole character and policy of the national government narrowly escaped being determined by the skillful introduction of a single phrase of only three words into a letter which afterwards proved to be a forgery. So characteristic of the alleged author was this phrase that at first even those who knew him best were reluctant to deny its authenticity. And yet I have excellent reasons for believing that the distinguished statesman whose splendid career was thus imperilled was entirely unconscious of the uncommon frequency with which this phrase occurred in his speaking and in his writing. It is because the scheme of the 'characteristic curve' lends itself to the development in a purely mechanical way of idiosyncrasies of which the author must be unconscious that it is thought to have some value as a means of identification. It may be that this as-

sumption has not yet been proved, but in view of what has been said and even of what was said twenty years ago, it can not be said to have been disproved. If instead of making deductions from groups of 1,000 to 5,000 words, Dr. Moritz had declared his belief that even 100,000 was too small a number for a perfectly definite characteristic curve the statement would have been well worth consideration; but it is difficult to doubt the evidence of diagrams exhibiting the word curves of several of the principal writers of Shakespeare's time, published in this journal, December, 1901, nearly all of which are based on counts of over 100,000 words each, and especially the very remarkable agreement, amounting to practical identity of the two curves from Shakespeare, each including about 200,000 words; the almost equally close agreement of two curves of 75,000 words each from Ben Jonson; and the striking difference between the latter and the curve of Shakespeare, although the 'form of composition' is the same in both, a fact directly opposed to Dr. Moritz's conclusion from a few groups of 5,000 words each.* After the reader has examined the close agreement of these large groups from the same author, he may consider the contrasted curves of Bacon and Shakespeare, representing the counts of over a half million words, and, as far as I am concerned, he is still 'at liberty to draw any conclusion he pleases.'

Dr. Moritz's studies of the influence of 'form of composition' on the word curve are instructive and it is to be hoped that he will have the patience and courage to continue them. When his word counting, instead of including only a few thousands, shall have reached a million or two, and these of not more than a half dozen authors, what he may have to say upon the subject will be listened to with interest.

T. C. MENDENHALL.

FLORENCE, ITALY,
June 24, 1904.

* It is interesting to compare diagrams 8, 11 and 14 of his paper, to note the *general* agreement of the two curves for each author, the general and, indeed, striking differences among the three authors (which would have been much more evident in *means* of the several pairs) and to inquire if he has even correctly interpreted his own diagrams?

Very truly yours
Joseph LeConte

THE PROGRESS OF SCIENCE.

THE LE CONTE MEMORIAL LODGE.

Joseph Le Conte died in the Yosemite Valley in 1901, and a memorial lodge has now been erected there in his honor by the Sierra Club. As the illustrations show the lodge is built in a manner appropriate to its beautiful surroundings. The stonework is of granite obtained in the vicinity with the weathered surface exposed, and the interior roof beams are uncovered. The main reading room is 36 x 25 feet in size. The lodge is overshadowed by the great cliffs of Glacier Point; there is a fine grove of trees in the rear, and the entrance commands a magnificent view. The structure was designed by Mr. John White and erected at a cost of about $5,000, subscribed by Le Conte's students, colleagues and friends, and members of the Sierra Club. It is most appropriate that there should be erected to Le Conte a memorial of this character, in this region that he loved so well and where he died, not a mere monument, but a building useful in promoting the out-of-door interests and scientific pursuits, which in his life time he greatly forwarded.

The Le Conte Memorial Lodge. Photographed by Hallett-Taylor Co.

There has recently been published by the Appletons an autobiography of Le Conte which, though written only as a manuscript for his family, presents a pleasing account of an interesting and lovable man, who held an important place in the scientific life of the country for more than fifty years. Joseph Le Conte was born on a Georgia plantation in 1823. His father was a scien-

INTERIOR OF THE LE CONTE MEMORIAL LODGE. Photographed by Hallett-Taylor Co.

tific man though he did not publish his work. His uncle, John Le Conte, was a naturalist, whose son, John Lawrence, was an eminent entomologist. His brother was a prominent physicist. A nephew is one of our leading physicists, and his son is a scientific man. Joseph, John and John Lawrence Le Conte were all members of the National Academy of Sciences, whose membership has included approximately only the two hundred leading American men of science of the past half century. We have here a very clear case of scientific heredity or family tradition.

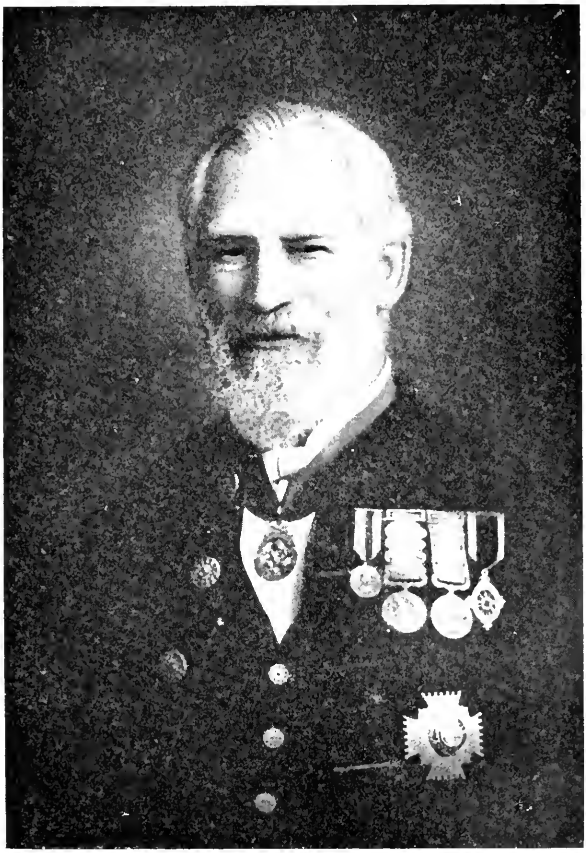
Le Conte belonged to the type of scientific man that can scarcely survive under the conditions of modern specialization. He taught practically all the sciences, including mathematics, with French added. He made contributions to geology, zoology and psychology, and wrote much on the theory of evolution and the relations of science to religion. We can not here undertake to give an account of his life, not in itself eventful but covering a wide field and a long time, touching the south, the north and the west. We must refer readers to the autobiography for an account of the life and life-work of a single-minded and truly great man.

SIR WILLIAM FLOWER.

FLOWER was one of the notable group of naturalists who gave distinction to Great Britain during the second half of the nineteenth century. He can not be ranked with Darwin, scarcely with Huxley, but his contributions to comparative anatomy and to museum administration were of the highest importance. Five years after his death a memoir has been prepared by Mr. C. J. Cornish with the cooperation of his son and of Lady Flower. The title page states that the work is 'a personal memoir.' In view of this explicit statement it would perhaps be unfair to criticize the book for paying more attention to Flower's high character, his beautiful family life, his christian faith and his relations with the nobility than to his contributions to science and

to the scientific development of Great Britain during the Victorian era. A life of Flower or of one of the other scientific leaders of the period written on the lines of Mr. Morley's great 'Life of Gladstone' would certainly be more valuable to the world than a personal memoir. While we have no right to demand such a biography from Mr. Cornish, we may regret that the memoir is from the scientific side superficial and even inaccurate. For example it is recorded in the title page that Flower was 'Late Director of the Natural History Museum, and President of the Royal Zoological Society.' Flower was in fact director of the Natural History Department of the British Museum and president of the Zoological Society of London.

Flower was born in 1831, his father being a brewer of Stratford-on-Avon, who spent his youth in America. As has been the case with many scientific men, Flower's early education was irregular; he was as a boy devoted to natural history, learning to stuff birds at the age of ten and establishing a 'museum.' He secured a medical education at University College, London, and served as a surgeon in the Crimean war. He married in 1858 the daughter of Admiral W. H. Smyth, an astronomer, one of whose sons became eminent as an astronomer and one as a geologist, while a daughter married the



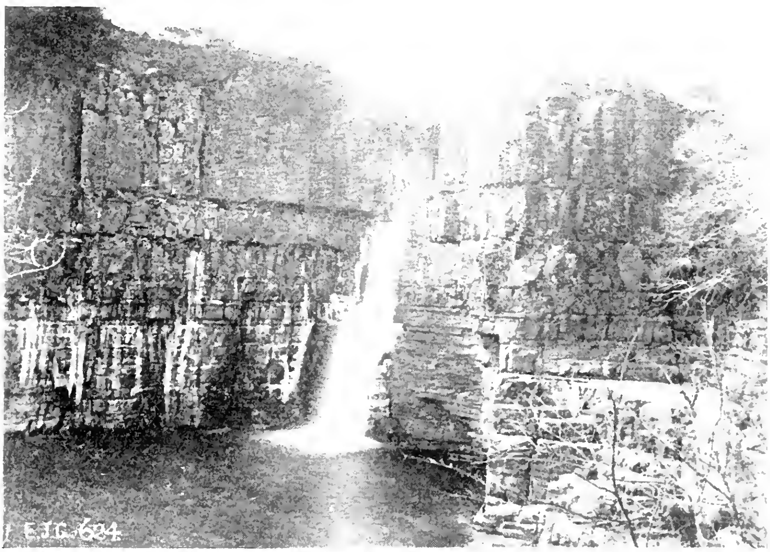
Sir William Flower, K.C.B.

Savilian professor of geometry at Oxford. Flower's family life with his seven children was particularly happy. At the age of thirty he gave up the practise of surgery to become conservator of the museum of the Royal College of Surgeons. Here he remained for twenty-two years until in 1884 he succeeded Owen as director of the Natural History Branch of the British Museum whose new building in South Kensington had been opened two years before. This position Flower held until his health failed in 1898.

During these years Flower published volumes on the osteology of the mammalia and on other subjects and a great number of special papers on comparative anatomy and zoology, on anthropology and on museum administration. Only three years after the publication of the 'Origin of Species' he arranged the collections of the Hunterian Museum to illustrate and as it were make tangible the doctrines of evolution. One of the steps in this direction consisted in obliterating the demarkation between recent and extinct forms. In many ways Flower made improvements in museum methods which have been followed everywhere. He had wide interests and filled many positions of trust and honor. Thus he was president of the Zoological Society of London from 1879 until his death in 1899.

GEOLOGICAL PHOTOGRAPHS.

Mr. Osmund W. Jeffs, in 1889, advocated the formation of a collection of geological photographs, and the committee of the British Association with this object in view was formed the following year. Mr. Jeffs acted as secretary of the committee until 1896, when he was succeeded by Professor W. W. Watts, and work has been carried forward actively, the number of photographs numbering 3,754 in 1903. In 1899 plans were made for the publication of a series of platinotype prints and lantern slides to be distributed to subscribers, and three issues containing seventy-two photographs have been issued. These photographs are accompanied by descriptions by well-known geologists and are of much scientific and educational value. We reproduce here two of the photographs.



The Whin Sill, Teesdale.

Mr. E. J. Garwood thus describes the Whin Sill, Hugh Force, Teesdale: This is a classical waterfall, described by Sedgwick in 1823, Wm. Hutton in 1831 and Phillips in 1836. The fall is 70 feet high, over the Whin Sill, which is here intrusive in the Lower Yoredale Beds. The photograph shows the chief fall near the right bank of the Tees. It is working along a joint in the hard Whin which forms the protective cap to the fall; when in flood surplus water also pours through a second joint near the left bank. The undercutting of the limestone is shown by the caves and the hanging icicles; the gorge below bears testimony to the recession of the falls. The section is as follows: Whin sill, 30 feet; shale, thinning out, 2 feet; whin, 9 feet; shale, altered, with superinduced prismatic jointing, 15 feet; hard limestone, with pyrites, 8 feet; hard, fossiliferous, crinoidal limestone, 20 feet; coralline limestone, 6 feet. The limestone is altered and saccharoidal to a distance of 35 feet below the base of the whin; the latter is of the normal type described by Teall.

Mr. W. A. E. Ussher gives an account of the natural arch at Torquay: The natural arch depicted in the photograph forms a conspicuous object on the south coast of the Torquay Promontory between the Bath Saloons and Daddy Hole. It has been tunneled by the sea through a small headland near the axis of an inverted synclinal curve in Middle Devonian Limestones. The prolongation of this axis eastward is well shown on the coast a quarter of a mile away. In the middle and lower part of the limestone masses of Torquay, a partial cleavage is often displayed by the beds, consequent on the pressure which has produced the folding in them; this structure, as shown in the photograph, becomes in certain cases most pronounced at and near the axis of the folds, causing a shattering of the rock at the point where the direction of strain cleavage approximates to, or coincides with, the inverted bedding planes. The dark marking extending

NATURAL ARCH AT TORQUAY.

horizontally on either side of the arch in the photograph denotes high water mark. The railings give a scale.

SCIENTIFIC ITEMS.

We record with regret the death of Dr. John Bell Hatcher, curator of vertebrate zoology at the Carnegie Museum, Pittsburg; of Dr. N. S. Davis, of Chicago, a voluminous writer on medical subjects and chairman in 1845 of a committee whose report led to the establishment of the American Medical Association; of M. Anatole de Barthélemy, the eminent French archeologist; of M. Léauté Sarrau, professor of mechanics in the Polytechnic School of the University of Paris, and of Dr. Fedor Bredichin, professor of astronomy at St. Petersburg.

Dr. W. H. Maxwell, superintendent of schools in New York City, has been elected president of the National Educational Association.—Dr. Louis S. McMurtry, of Louisville, Ky., has been elected president of the American Medical Association for the meeting to be held next year at Portland, Ore.—Professor George Darwin, of Cambridge, will succeed Mr. Balfour, the British premier, as president of the British Association, and will preside over the meeting to be held in South Africa next year.

Professor Simon Newcomb, U.S.N. (retired), has been elected corresponding member of the Berlin Academy of Sciences.—The honor of knighthood has been conferred on Professor James Dewar, the chemist, by King Edward.—The new chemical laboratory of the University of Utrecht, named in honor of Professor J. H. van't Hoff, has been formally opened. On the occasion Professor van't Hoff was given the honorary doctorate by the university.

President E. A. Alderman, of Tulane Univeristy, has been elected president of the University of Virginia. The University of Virginia, in accordance with the democratic ideas of Jefferson, has hitherto been governed by a board of visitors and the faculty without a president.—Dr. Charles Schuchert, of the U. S. National Museum, has been appointed professor of historical geology in the Sheffield Scientific School of Yale University and curator of the geological collections in succession to the late Professor Beecher.—Dr. Roux has been elected director of the Pasteur Institute in the room of the late M. Duclaux. Drs. Chamberland and Metchnikoff have been elected subdirectors of the institute.

At the alumni dinner of the State University of Iowa, the former students of Professor Samuel Calvin, to the number of over two thousand, united in the commemoration of the completion of his thirtieth year in a professorship at that institution. The recognition took the form of a costly silver loving-cup, designed especially for the purpose of symbolizing the scientific achievements of the recipient. The cup is a classic Greek vase, sixteen inches in height, and stands on a base of serpentine five inches high. It is adorned with casts taken directly from fossils, with a drainage-map of Iowa, with crossed geological hammers, a microscope, and the more conventional spray of laurel, owl of wisdom and torch of learning,—all in relief. One side bears an appropriate inscription in raised letters. Professor Calvin was elected to the chair of natural history in Iowa's university thirty years ago. The chair has since been subdivided into four distinct departments. Professor Calvin retaining the department of geology. He has been state geologist of Iowa during the last twelve years.

THE

POPULAR SCIENCE

MONTHLY.

SEPTEMBER, 1904.

THE DEVELOPMENT OF THE THEORY OF ELECTROLYTIC DISSOCIATION.*

By Professor SVANTE ARRHENIUS,

STOCKHOLM, SWEDEN.

AT first sight nothing seems to be more evident than that everything has a beginning and an end, and that it is possible to divide everything. Nevertheless, the philosophers of antiquity, especially the Stoicist, concluded, on purely speculative grounds, that these opinions are not at all necessary. The wonderful development of science has reached the same conclusion as these philosophers, especially Empedocles and Democritus, who lived about 500 years B. C., and for whom the ancients had already a vivid admiration.

Empedocles professed that nothing is made of nothing, and that it is impossible to annihilate anything. All that happens in the world depends upon a change of form and upon the mixture or the separation of bodies. Fire, air, water and earth are the four elements of which everything is composed. An everlasting circulation is characteristic of nature.

The doctrine of Democritus still more nearly coincided with our modern views. In his opinion bodies are built up of indefinitely small indivisible particles, which he called atoms. These are distinguished by their form and magnitude, and also give different products by their different modes of aggregation.

This atomic theory was revived by Gassendi about 1650, and then accepted by Boyle and Newton. The theory received a greatly increased importance by the discovery by Dalton of the law of multiple proportions. For instance, the different combinations of nitrogen with

* Address before the Royal Institution of Great Britain, June 3, 1904.

oxygen contain, for each unit weight of nitrogen, 0.57, 1.14, 1.72, 2.29 or 2.86 unit weights of oxygen.* Between these combinations there is no intermediate proportion. This peculiarity is characteristic of chemistry in contradistinction to physics, where the more simple continuous and gradual transition from one state to another prevails. This difference between the two sister sciences has often caused controversies in the domain of physical chemistry. The occurrence of discontinuous changes and of multiple proportions has frequently been assumed, when a closer investigation has found nothing of the sort.

The law of multiple proportions is the one fundamental conception upon which modern chemistry is built up. Another is the law of Avogadro, which asserts that equal volumes of different gases under like conditions of temperature and pressure contain the same number of molecules. This conception, dating from the beginning of the nineteenth century, was at first strongly combated, and it was its great value in explaining the new discoveries in the rapidly growing domain of organic chemistry which led to its general acceptance in the middle of the past century, after Cannizzaro had argued strongly in its favor.

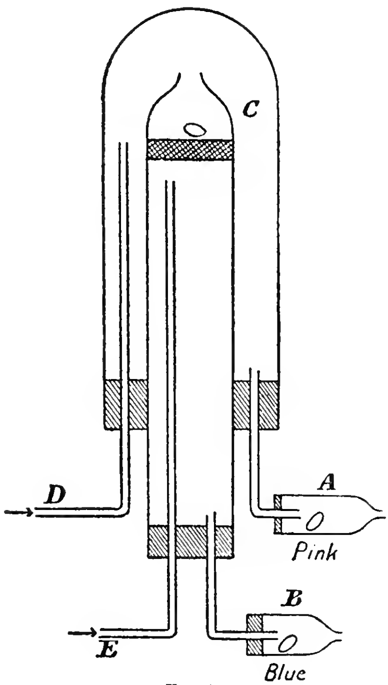


FIG. 1.

There were, however, some difficulties to be removed before Avogadro's law could be accepted. For instance, it was found that the molecular volume of sal-ammoniac, NH_4Cl, in the gaseous state was greater than might be expected from its chemical composition. This led to the supposition that the molecules of sal-ammoniac when in the gaseous state are partially decomposed into ammonia, NH_3, and hydrochloric acid, HCl. Indeed v. Pebal and v. Than succeeded in showing that this really happens. They used an apparatus that is shown in the annexed figure (Fig. 1). Two coaxial tubes are placed the one inside the other by means of a cork. The outer tube was closed at its upper end; the inner one was open and contained at C a diaphragm of asbestos and above that a piece of sal-ammoniac. The upper end was

* To explain this we suppose, in accordance with Dalton, that the molecules of the different combinations of nitrogen with oxygen contain two atoms of nitrogen and one, two, three, four or five atoms of oxygen.

heated by an air-bath, so that the piece of sal-ammoniac was volatilized. After this a current of hydrogen was led through both glass tubes D and E. Now ammonia diffuses more rapidly than hydrochloric acid; if, therefore, the vapor of sal-ammoniac is partially decomposed into ammonia and hydrochloric acid, we should expect that above the asbestos diaphragm there would be an excess of hydrochloric acid and beneath it an excess of ammonia. This v. Pebal showed to be the case. The hydrogen-current from D showed an acid reaction on a piece of litmus-paper in A, and that from E showed an alkaline reaction on a similar piece of litmus-paper placed in B. It was objected that the decomposition might possibly be caused by the asbestos of the diaphragm, or by the hydrogen. V. Than, therefore, made a diaphragm of sal-ammoniac, and substituted nitrogen for hydrogen, but the effect was the same.

These experiments were performed in the years 1862 and 1864. They were based on the doctrine of dissociation, which was at that time (1857) worked out by Ste. Claire-Deville, and developed by his pupils. From the most ancient times use was made of the fact that limestone at high temperatures gives off carbonic acid, and that quick-lime remains. This and similar processes were studied by Ste. Claire-Deville. He found that the same law is valid for the pressure of carbonic acid over limestone and for the pressure of water vapor over liquid water at different temperatures. On these fundamental researches the theory of dissociation was based, a theory which has subsequently played an ever-increasing rôle in chemistry, and whereby a broad bridge was laid between physical and chemical doctrines.

At almost exactly the same time we find in the writings of Clausius on the conductivity of salt solutions the first traces of an idea that salts or other electrolytes may be partially dissociated in aqueous solutions. Buff had found that even the most minute electric force is sufficient to drive a current through a solution of a salt. Now after the scheme of Grotthuss, at that time generally accepted, the passage of the electric current through a solution is brought about in such manner that the conducting molecules, *e. g.*, of potassium chloride (KCl), are divided into their ions, which combine again with one another in the following manner: At first, as the current is closed, the electrode A becomes positive and the electrode B negative. All the conducting molecules KCl arrange themselves so that they turn their positive ions (K) to the negative electrode B, and their negative ions (Cl) to the positive electrode A. After this, one chlorine ion is given up at A and one potassium ion at B, and the other ions recombine, so that the K of the first molecule takes the Cl of the second molecule, and so on (Fig. 2). Then the molecules turn round under the influence of the electric force, so that we get the scheme 3 and a new decomposition

can take place. This represents the Grotthuss scheme, that supposes continuous decompositions and recombinations of the salt molecules.

As such exchanges of ions between the molecules take place even under the influence of the weakest electromotive forces, Clausius concluded that they must also take place if there is no electric force, *i. e.*, no current at all. In favor of his hypothesis he pointed to the fact that Williamson, as far back as 1852, in his epoch-making theory of the formation of ethers, assumed an analogous exchange of the constituents of the molecules. At this exchange of ions it might sometimes, though extremely rarely, happen that an ion becomes free in the solution for a short time; at least such a conception would be in good agreement with the mechanical theory of heat, as it was developed by Krönig, Maxwell, Clausius and others at that time.

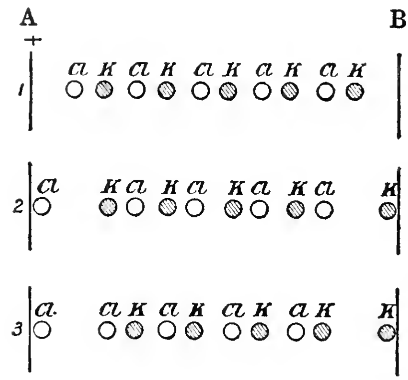


FIG. 2.

In the meantime, Bouty, and particularly Kohlrausch, worked out the methods of determining the electric conductivity of salt solutions. In 1884 I published a memoir on this subject. I had found that if one dilutes a solution—*e. g.*, of zinc sulphate—its conductivity per molecule, or what is called its molecular conductivity, increases not infinitely, but only to a certain limit. We may figure to ourselves an experiment performed in the following manner (Fig. 3): In a trough with parallel walls there are placed close to two opposite sides two plates of amalgamated zinc, E E_1. On the horizontal bottom of the vessel there is placed a layer of solution of zinc-sulphate that reaches the level 1. The conductivity may be k_1. After this has been measured we pour in so much water, that after stirring the solution the level reaches 2, which lies as much above 1 as this lies above the bottom. The conductivity is then found to be increased, and to have the value k_2. Increasing in the same manner the volume by addition of pure water until it is doubled, the level 4 is reached and the

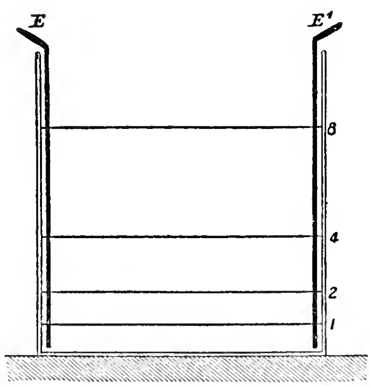


FIG. 3.

conductivity is found to be greater than in the previous case—say k_4. So we may proceed further and further; the conductivity increases, but at the end more slowly than at the beginning. We approach to a final value k_8. This is best seen in the next diagrams, which represent the newer determinations of Kohlrausch (Figs. 4, 5).

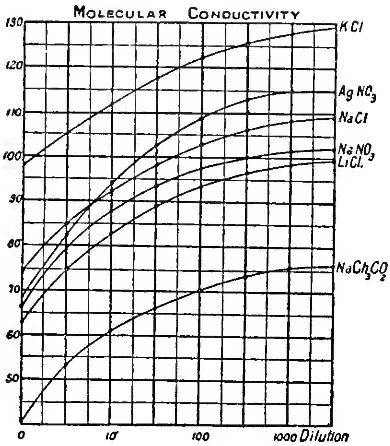


FIG. 4.

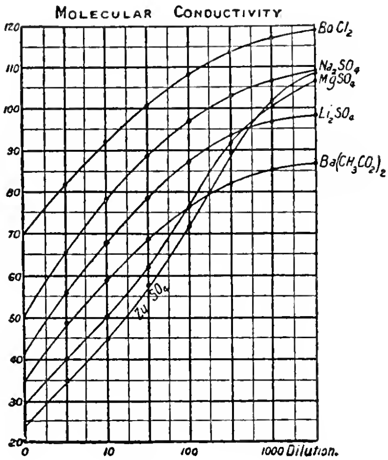


FIG. 5.

I explained this experiment in the following manner: The conductivity depends upon the velocity with which the ions (Zn and SO_4) of the molecules ($ZnSo_4$) are carried through the liquid by the electric force, *i. e.,* the potential difference between E and E_1. If this potential difference remains constant, the velocity depends only on the friction that the ions in their passage through the liquid exert on the surrounding molecules. As these, at higher dilutions, are only water molecules, it might be expected that the conductivity would remain constant and independent of the dilution if it be supposed that all molecules, $ZnSO_4$, take part in the electric transport. As experiment now teaches us that the molecular conductivity increases with the dilution, even if this is very high (1,000 or more molecules of water to one molecule of $ZnSO_4$), we are led to the hypothesis that not all, but only a part of, the $ZnSO_4$ molecules take part in the transport of electricity. This part increases with the dilution in the same proportion as the molecular conductivity k. The limiting value k_8 is approached at infinite dilution, and corresponds to the limit that all molecules conduct electricity. The conducting part of the molecules I called the active part. It may evidently be calculated as the quotient $k:k_8$.

If now this new conception were only applicable to the explanation of the phenomena of electric conductivity, its value had not been so

very great. But an inspection of the numbers of Kohlrausch and others for the conductivity of the acids and bases, compared with the measurements of Berthelot and Thomsen on their relative strength with regard to their chemical effect, showed me that the best conducting acids and bases are also the strongest. I was thereby led to suppose that the electrically active molecules are also chemically active. On the other hand, the electrically inactive molecules are also chemically inactive. In this connection I would mention the remarkable experiments of Gore, which were easily explained by the new point of view. Concentrated hydrochloric acid, free from water, has no action on oxides or carbonates. Now this hydrochloric acid is almost incapable of conducting the electric current, whereas its aqueous solutions conduct very well. The pure hydrochloric acid contains, therefore, no (or extremely few) active molecules, and this agrees very well with the experiments of Gore. In the same way we explain the fact that concentrated sulphuric acid may be preserved in vessels of iron plates without destroying them, whereas this is impossible with the diluted acid.

An unexpected conclusion may be deduced from this idea. As all electrolytes in extreme dilution are completely active, then the weak acids must increase in strength with the dilution, and approach to the strength of the strongest acids. This was soon afterwards shown by Ostwald to agree with experiments.

The Norwegian natural philosophers, Guldberg and Waage, had developed a theory according to which the strength of different acids might be measured as well by their power of displacing another acid in solutions as by their faculty to increase the velocity of chemical reactions. Therefore, we may conclude that the velocity of reaction, induced by an acid, would be proportional to the quantity of active molecules in it. I had only a few experiments by Berthelot to demonstrate this proposition, but in 1884, Ostwald published a great number of observations that showed this conclusion to be true.

The most far-reaching conclusion of the conception of active molecules was the explanation of the heat of neutralization. As this is much more easily understood by means of the theory of electrolytic dissociation, I anticipate this for a moment. According to this theory strong acids and bases, as well as salts, are at great dilution (nearly) completely dissociated in their ions, *e. g.*, HCl in $\overset{+}{\mathrm{H}} + \overset{-}{\mathrm{Cl}}$, NaOH in $\overset{+}{\mathrm{Na}} + \overset{-}{\mathrm{O}}\mathrm{H}$ and NaCl in $\overset{+}{\mathrm{Na}} + \overset{-}{\mathrm{Cl}}$. But water is (nearly) not dissociated at all. Therefore the reaction of neutralization at mixing a strong acid, *e. g.*, HCl with a strong base, *e. g.*, NaOH, both in great dilution, may be represented by the following equation:

$$(\overset{+}{\mathrm{H}} + \overset{-}{\mathrm{Cl}}) + (\overset{+}{\mathrm{Na}} + \overset{-}{\mathrm{O}}\mathrm{H}) = (\overset{+}{\mathrm{Na}} + \overset{-}{\mathrm{Cl}}) + \mathrm{HOH};$$

or,

$$\overset{+}{H} + \overset{-}{OH} = HOH.$$

The whole reaction is equivalent to the formation of water out of both its ions, $\overset{+}{H}$ and $\overset{-}{OH}$, and evidently independent of the nature of the strong acid and of the strong base. The heat of any reaction of this kind must, therefore, always be the same for equivalent quantities of any strong acids and bases. In reality it is found to be 13,600 cal. in all cases. This thermal equality was the most prominent feature that thermochemistry had discovered.

It was now asked in what respect the active state of the electrolytes differs from the inactive one. On this question I gave an answer in 1887. At that time van't Hoff had formulated his wide-reaching law that the molecules in a state of great dilution obey the laws that are valid for the gaseous state, if we only replace the gas-pressure by the osmotic pressure in liquids. As van't Hoff showed, the osmotic pressure of a dissolved body could much more easily be determined by help of a measurement of the freezing point of the solution than directly. Now both the direct measurements made by De Vries, as also the freezing points of electrolytic solutions, showed a much higher osmotic pressure than might be expected from the chemical formula. As, for instance, the solution of 1 gram-molecule of ethylic alcohol—$C_2H_5OH = 46$ grams—in one liter gives the freezing-point $-1.85°$ C., calculated by van't Hoff the solution of 1 gram-molecule of sodium chloride—$NaCl = 58.5$ grams—in one liter gives the freezing-point $-3.26 = -1.75 \times 1.85°$ C. This peculiarity may be explained in the same manner as the 'abnormal' density of gaseous sal-ammoniac, viz., by assuming a partial dissociation—to 75 per cent.—of the molecules of sodium chloride. For then the solution contains 0.25 gram-molecules of NaCl, 0.75 gram-molecules of Cl and 0.75 gram-molecules of Na; in all, 1.75 gram-molecules. Now we have seen before how we may calculate the number of active molecules in the same solution of sodium chloride, and we find by Kohlrausch's measurements precisely the number 0.75. From this I was led to suppose that the active molecules of the salts are divided into their ions. These are wholly free and behave just as other molecules in the solutions. In the same manner I calculated the degree of dissociation of all the electrolytes that were determined at that time—they were about eighty—and I found in general a very good agreement between the two methods of calculation. In a few instances the agreement was not so good; I therefore made new determinations for these bodies and some others. The new determinations were all in good conformity with the theoretical prevision.

The next figure (Fig. 6) shows the freezing-points of some solution of salts, and of non-conductors. As abscissa is used the molecular concentration of the bodies, as ordinates the molecular depression of

the freezing-point, divided by 1.85, that should be expected if no dissociation took place. As the figure shows, all the curves for the non-conductors—in this case cane-sugar, propyl-alcohol and phenol—converge towards unity with diminishing concentration. At higher concentrations there occur deviations from the simple law. As examples of binary electrolytes are chosen LiOH, NaCl and LiCl—their curves all converge towards the number 2. As ternary electrolytes are chosen K_2SO_4, Na_2SO_4, $MgCl_2$ and $SrCl_2$, they are decomposed into three ions, and their curves therefore all converge towards the number 3.

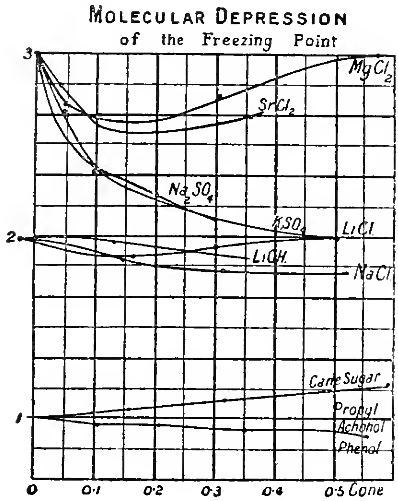
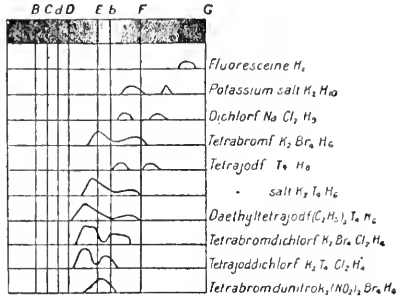


FIG. 6.

As I had taken a step that seemed most adventurous to chemists, there remained to investigate its chemical and physical consequences. The most general and wide-reaching of these is that the properties of a highly attenuated solution of an electrolyte ought to be additive, that is, composed of the properties of the different ions into which the electrolyte is decomposed. This was already known to be the case in many instances, and Valson had to this end tabulated his 'modules' by the addition of the one value for the negative to the other for the positive ion, we may calculate the properties of any electrolyte composed of the tabulated ions. In this way we may treat the specific weight (Valson), the molecular conductivity (law of Kohlrausch), the internal friction (Arrhenius), the capillarity (Valson), the compressibility (Röntgen and Schneider), the refractive index (Gladstone), the natural rotation of polarization (law of Oudemans), the magnetic rotation of polarization (Perkin and Jahn), the magnetization (Wiedemann), and all other properties of the electrolytes hitherto sufficiently studied.

The most important of these additive properties are those of which we make use in chemical analysis. As is well known, it is generally true that chlorides give a white precipitate with silver salts. It was said formerly that silver salts are reagents for chlorine. Now we say that silver ions are reagents for chlorine ions. This expression is better than the old one, for neither all silver salts, *e. g.*, potassium silver cyanide and many other compounds of silver, nor all chlorine compounds, *e. g.*, potassium chlorate and many organic chlorides, give this characteristic reaction. The experiment succeeds only with such

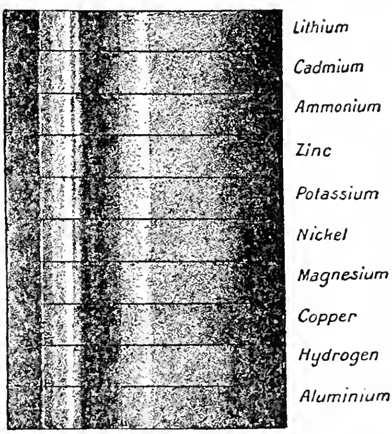
silver and chlorine compounds as are in a measurable degree decomposed into silver and chlorine ions. Ostwald has treated this question comprehensively, and in this way he has given a rational exposition of the general phenomena of analytical chemistry. To this fact belong, also, the poisonous effect of some salts; this effect may be considered as a special physiologically chemical reaction of the chemical compounds. On this point there are many valuable researches by Krönig and Paul, Clarke and others.



Derivates of Fluoresceine $H_{12}C_{20}O_5$

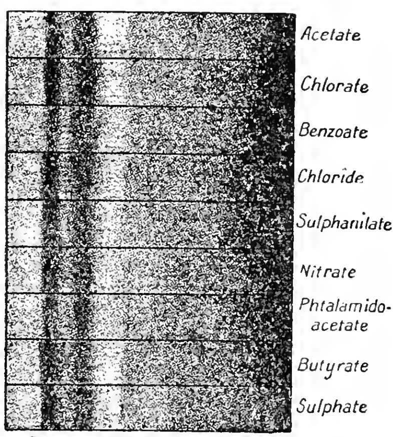
FIG. 7.

A property that is of physical character, but is much used by the analytical chemist, is the color of the solutions. It has been subjected to a rigorous research by Ostwald. At first we will trace how a compound, *e. g.*, fluoresceine, $H_{12}C_{20}O_5$, behaves if one replaces its hydrogen atoms by other atoms, *e. g.*, metals, iodine, bromine or atomic groups (NO_2). The curves in the next figure (Fig. 7) indicate absorption-bands in the spectra of the corresponding compounds. A replacement of K_2 for H_2 in the fluoresceine itself alters the absorption-spectrum in a most sensible manner. This depends upon the property that the fluoresceine is dissociated to a slight extent, which is in striking con-



Permanganates

FIG. 8.



Salts of Pararosaniline

FIG. 9.

trast to the permanganic acid which will be discussed immediately. Instead of a single absorption-band in the blue in the first case, we find two absorption-bands in the blue-green and the green part of the spec-

trum for the second. A similar observation may be made for the tetraiodine-fluoresceine and its potassium salt. In general the figure shows that the spectrum is changed in a very conspicuous manner at the smallest chemical change of the molecule.

It might therefore be expected, after the old manner of view, that the replacement of hydrogen by a metal in permanganic acid, or of one acid rest by another in the salts of para-rosaniline, would wholly change the character of the spectra. This is not the case, as Ostwald has shown. The spectra are wholly unchanged, as Figs. 8 and 9 show. The spectra are all produced by the same substance, viz., the permanganate-ion, in the one, the para-rosaniline-ion, in the other case. Only in the case of the para-rosaniline salts we observe that the absorption is sensibly weaker in some cases than in others. The weakening depends upon the hydrolysis of the salts of the weak acids, *e. g.*, acetic and benzoic acids. This research of Ostwald shows in a most convincing manner the correctness of the views of the theory of electrolytic dissociation.

It has been objected to this theory, that according to it it might be possible by diffusion to separate both ions, *e. g.*, chlorine and sodium, from another in a solution of sodium chloride. In reality chlorine diffuses about 1.4 times more rapidly than sodium. But the ions carry their electric charges with them. Therefore if we place a solution of sodium chloride in a vessel and we pour a layer of pure water over it, it is true that in the first moments a little excess of chlorine enters the water. By this the water is charged negatively, and the solution under it positively, so that the sodium ions are driven out from the solution with a greater force than the chlorine ions. As soon as that force is 1.4 times greater than this, the chlorine ions travel just as slowly as the sodium ions. It is not difficult to calculate that this case happens as soon as the chlorine ion is contained in the water in an excess of about the billionth part of a milligram over the equivalent quantity of sodium. This extremely minute quantity we should in vain try to detect by chemical means. By electrical means it succeeds pretty well, as Nernst has demonstrated experimentally for his concentration elements. Therefore, the said objection is valid against the hypothesis of a common dissociation of the salts, but not against a dissociation into ions, that are charged with electricity, as Faraday's law demands. Probably this objection has hindered an earlier acceptance of a dissociated state of the electrolytes, to which, for instance, Valson and Bartoli inclined.

The gaseous laws that are valid for dilute solutions have made the calculation of the degree of dissociation possible in a great number of cases. The first application of that nature was made by Ostwald, who showed that the dissociation equilibrium between the ions and the non-

dissociated part of a weak acid obeys very nearly the gaseous laws. The same was afterwards demonstrated to be true for weak bases by Bredig. The strongly dissociated electrolytes, chiefly salts, exhibit even in dilute solutions (over 0.05 normal) anomalies, that are not yet wholly explained. Professor Jahn, of Berlin, is at work upon this most interesting question.

The equilibrium between a greater number of electrolytes has been investigated by myself, and found to be in good agreement with the theoretical previsions. This section includes the questions on the weakening of an acid by addition of its salts, and on the so-called avidity of the different acids, that is, the proportion in which two acids divide a base at partial neutralization. Calculation gives very nearly the numbers observed experimentally by Thomsen and Ostwald. For heterogeneous equilibria between electrolytes the theory is worked out by van't Hoff and Nernst, who have in this way elucidated the common method to precipitate salts used in analytical chemistry.

By help of the gaseous laws it is also possible to determine the heat evolved at the dissociation of a weak acid or base, and in this way I was able to calculate the heat of neutralization of acids and bases in a general manner. In an analogous way, Fanjung calculated the changes of volume at dissociation of a weak acid or base and at the neutralization of these bodies. All these calculations gave values very nearly agreeing with the observed ones.

An important rôle is played by the water, which may be regarded as a weak acid or base. By its electrolytical dissociation it causes the hydrolysis of salts of weak acids and bases. By observation of the hydrolysis, it was possible to calculate the electrolytic dissociation of water, and this quantity was soon after determined by electrical measurements by Kohlrausch and Heydweiller in perfect agreement with the previous calculations. For physiological chemistry this question is of the greatest importance, as is confirmed by the experimental results of Sjögvist and others. Also for the explanation of volcanic phenomena, the concurrence between water and silicic acid at different temperatures has found an application.

The catalytic phenomena in which acids and bases are the chief agents, have been investigated by many observers, and it has been found that the catalytic action depends on the quantity of free hydrogen or hydroxyl ions that are present in the solution. To this review, that makes no pretension to be complete, may also be added the wide-reaching researches of van't Hoff, Ostwald, and especially Nernst, on the electromotive forces produced by the ions. By these investigations we have now acquired an explanation of the old problem of the manner in which electromotive forces in hydro-electric combinations are excited.

I have now traced the manner in which the idea of electrolytic

dissociation grew out of our old conception of atoms and molecules. Sometimes we hear the objection that this idea may not be true, but only a good working hypothesis. This objection, however, is in reality no objection at all, for we can never be certain that we have found the ultimate truth. The conception of molecules and atoms is sometimes refuted on philosophical grounds, but till he has got a better and more convenient representation of chemical phenomena, the chemist will, no doubt, continue to use the atomic theory without scruple. Exactly the same is the case for the electrolytic dissociation theory.

This theory has shown us that in the chemical world the most important rôle is played by atoms or complexes of atoms, that are charged with electricity. The common tendency of scientific investigation seems to give an even more preponderating position to electricity, the mightiest agent of nature. This development is now proceeding very rapidly. Already we see not only how the theory of electrons of J. J. Thomson, in which matter is reduced to a very insignificant part, is developing, but also how efforts are made with good success to explain matter as only a manifestation of electrodynamic forces (Kaufmann-Abraham).

To these modern developments the work of British men of science has contributed in the most effective manner. The bold previsions of Sir William Crookes seem to be rapidly acquiring a concrete form, to the great benefit of scientific evolution.

CONSERVATION OF HUMAN ENERGY, PRESERVATION OF BEAUTY.

By Dr. J. MADISON TAYLOR,
PHILADELPHIA, PA.

THE paramount importance of retaining human beauty is a fact requiring so little demonstration as to simulate a fundamental truth. All historical records bear witness to this verity. Popular interest seems extraordinarily awakened in this direction of late years, and in particular the daily press teems with observations on the subject. Much of it, however, is misleading and liable to bring a really vital subject into contempt. This paper is the expression of a desire on the part of the writer to place the matter on the plane which it deserves. Whatever merit the following observations contain, at least they seem to the writer worth offering, being the result of practical labors in the right direction, and from which satisfactory results are known to have come to a few faithful followers. It will be admitted, too, that the theme eminently merits the attention of all; for if so much of beauty as has been vouchsafed to each can be retained beyond the period when that elusive quality ordinarily subsides, it is a quest justifying some effort.

It is not to be expected that delicacy of coloring in skin or hair, the special prerogative of youth, shall be preserved beyond early middle life. Arduous attempts to modify the inevitable changes which normally appear in these tissues, are of doubtful efficiency, even questionable propriety. It is true that through the exercise of care and temperance much may be done to postpone serious marring of the skin texture and quality, but coloring must change. Nor is it advisable to resent this. Beauty of youth is *sui generis;* so is that of maturity; and it is the part of wisdom for each one to adopt measures which shall bring about a fitness in appearance consistent with the actual age reached. It is, however, entirely possible to postpone indefinitely those changes in bulk and contour, in form, in poise, in gait and carriage, which arise chiefly from neglect of suitable precautions; for these defects need not obtrude till toward the end of a long and busy life. History, both ancient and modern, is replete with examples of persons who, appreciating these facts, have enjoyed well-deserved reputations for great charm of appearance, especially grace and symmetry, well beyond the fifth and sixth decades. We have in our time conspicuous instances of

men, and women also, who are of the age of grandparents, and yet are altogether attractive and beautiful.

The time was, and recent too, when most men on reaching the age of thirty-five or forty adopted a quiet costume and demeanor of stability and left off regarding themselves as sharing in any part of their resigned youth. The same voluntary transition was even more noticeable among women, especially the married ones. When the duties of life lay most largely about the domestic hearth the duties and privileges of parenthood were accepted and enjoyed with no, or little, thought of acquiring the pose of perpetual adolescence. A change has been wrought, for good or otherwise, and it becomes a matter of common remark that we have no middle-aged folk any more. People are either young or they are old. As for inevitable conditions, little need be said; they must be accepted and made the most of. It has been decided, however, that now-a-days we shall stay young as long is possible, hence it behooves those of us who are the conservators of health to teach our clients the best measures by which youthfulness may be conserved and cellular structures held in equipoise.

There is much to be said in favor of such a decision. Assuredly, a man is to be commended for desiring to see the wife of his bosom long retain those qualities which first swayed his judgment and determined his choice. The Almighty put into the heart of his people certain instinctive impulses, the following of which brings about mating. Beauty of face and form, varying as it inevitably must, in accordance with racial or local standards, is the deciding factor in espousals. No doubt we can be made to believe that soul appeals to soul in these momentous yet sudden decisions, which we all made, and our children will make yet after us. But comeliness is and should be the final arbitrament. Happily there are many types and adequate varieties.

"There is a beauty of the flesh, and there is likewise a glory of the spirit which illumines the flesh. In the most pleasing of human countenances these good gifts are blended in just, though varying, degrees." It is possible for one or the other extreme to prevail and each be satisfactory to the beholder. This again depends upon the caliber of the spectator; his or her mood and training. If the spirit works so powerfully here as some would have us believe, it follows that the wisest men and women should make their choice less by reason of propinquity than is demonstrated by history and experience. The instinctive impulses are primarily wholesome, and make for good, but, unless modified by judgment, tend inevitably toward selfish indulgences which mar the most beautiful human complex.

It would seem pertinent, however, to make some effort at understanding what the elements of that beauty are, which is so well worth the preserving. While this concept might be attained, it is by no

means certain that it could be reduced to words, or formulated with exactness. Standards of beauty exist consonant with views not fixed and immutable, varying with many factors, racial, national or local, and fluctuating with fashion and accident or precedent. There is great dearth of agreement among the arbiters, and those who have been most industrious in promulgating their views differ so widely that we are, in the main, reduced to accept individual opinions, and our own always seems the most rational or acceptable. However, allowing for the great diversity which exists between the standards prevailing in Darkest Africa, the Valley of the Amazon, the South Sea Islands and New York or Paris, certain rules hold good, with rare exceptions.

As to the features of the face we need offer few comments; this would become too wide a discussion. The largest measure of beauty capable of preservation lies in the contours and poses of the body. It will be useful to indicate briefly what standards should be held in mind toward which to strive. Ease of movement and gracefulness of carriage are at the basis of what is called style. The other elements are dignity and restraint, betraying reserve power; always normality and accuracy of coordination and suitability of action consistent with the demands of environment and circumstances. The term 'well set up' is often used and may be taken to evidence such balance in the tension of the opposing symmetrical muscles as shall preserve a nicety of equipoise with economy in motor energizing, so that each movement follows with accurate and unconscious, though restrained, force. Full relaxation is the starting point of all effort; the conservator of action.

One so endowed will be found, as a rule, to exhibit a straight back, the spinal column practically vertical, viewed from the rear, and when looked at from the side, the normal curves at neck and waist line will be distinctly less marked than common. The pelvis will be nearly on a level and not markedly tilted forward and down in front, so obvious in fat people or those of lax fiber. The shoulders are held well down and directly in the mid-line (viewed from the side), but with the ribs more nearly at right angles to the spinal column than is seen in those who exhibit exaggerated nuchal and lumbar curves. The head is well balanced upon a round straight neck, which is slightly inclined forward, and there will be almost no curve in the upper thoracic vertebræ. A vertical line would fall from the back of the head to the middle of the shoulders. These features originally possessed or acquired, as they can be, make possible a slimness of waist fully compatible with health. If this attitude is maintained the depth of the chest consists of an elevated position of the ribs, giving them their largest diameters, antero-posteriorly and laterally.

The level pelvis and relatively straight lumbar spine compel a wholesome action of the abdominal parietes, by which full support of

the loosely attached abdominal organs is maintained and the waist kept small, preventing unsightly thickening of the tissues in this region.

A small waist is only beautiful if the lateral line drops into the hip gradually and passes out over the hip bone in a steady but not sudden curve. If the curve dips in abruptly and springs over the hip bone at an acute angle, giving a waspish appearance to the waist, it argues for flabby tissues about the abdomen, sides and back. Such slimness evinces a lack of early development, weak digestive and other vital organs, and tendency to speedy shapelessness. It is a difficult matter to regain vigor in such tissues. The upper chest should be full and fairly broad, and if the collar bones show, as is often seen in both plump and thin people, some fault exists in the tension of the muscles and tissues of the thorax, shoulders and back and the lungs have not attained full apical expansion. This being overcome, the clavicles should not appear at all, because the ribs will then be held normally and nearly at a right angle to the spinal column. There should be ample space in the lower rib areas, indicating lung room and vigor of diaphragm. The arms should hang easily, without tension, and fall a little in advance of the middle of the hip bone. Any stiffness in the arms or shoulders or elbows makes for awkwardness. In walking, the pelvis should be kept practically level, the tissues between the shoulder blades and along the backbone should hold the chest erect and keep the breastbone well up in front. Then the thighs will be able to move easily with no undue weight falling on the heel. If a person strikes the heel heavily on the ground in walking, these precautionary points are neglected and grace can not follow. The normal sway of the arms in walking is slightly toward the mid line in front; any tendency for them to fall toward the back, or worse than all, behind the back, is a hideous fault, and unless the back is grossly curved, causes the body to pitch forward clumsily on the heels. A good rule is to keep the base of the neck well back against the collar and the lobes of the ears as far as possible above the tips of the shoulders.

It is obvious that to retain beauty one of the first considerations must be to habitually exercise economy of all the natural forces; avoiding so much of those wastefulnesses of wear and tear as is possible in the ordinary exigencies of daily life. It may be answered to this truism that it is scarcely feasible, or indeed desirable, to order one's life on such a plane of artificiality or selfishness, as shall make for the shirking of communal labors and responsibilities. This need not be claimed as the result of the practise of these normal economics. It should be the duty of all teachers, parental or professional, to inculcate in the young a philosophic attitude toward annoyances, disappointments, even calamities, for of these every mother's child of us

must meet his full share. Indeed, to escape all such vexations would by no means tend to elevate the soul or ennoble the mind, but rather evolve an insipid character, bereft of the essential attributes which make for that perfect quality of spirit, the possession of which can alone impart a desirable beauty to the countenance. "Fortitude, steadfastness and the makings of character come not of rainbow dawns and quiet evenings and the facile attainments of small desires;" and the defences against ugliness which wealth and position are supposed to afford (by those who have them not) are at best disappointing. A little with contentment is admittedly the ground of great gain. Again, labors and the meeting of difficulties hurt neither body nor spirit unless they so affect both that the habit of worry inculcates a mental bias toward peevishness or despair. Nothing mars the human image of God so swiftly and inevitably as fretfulness and complainings. So true is this, as an item of common knowledge, that the countenances of chronic invalids and real sufferers are known often to be, and remain through long painful years, beautiful and satisfying. Again it frequently happens that persons thus successful in enjoying for themselves, and presenting to their friends, a fund of pleasure and satisfaction, did not originally possess the key to this boon, but acquired their charm by wisely schooling their minds until the blessing came. Much more could be said to demonstrate that features, mental or physical, which one may greatly desire can often be gained in spite of original shortcomings and the buffets of fate. So much then for the higher possibilities which lie open to those who earnestly desire to do, or be, or get something better than their circumstances seem to warrant.

In securing economy of the vital forces, admittedly so desirable, the chief factor is to conserve the ebb and flow of innervation. This is the key to the situation. The cellular waste may be estimated as direct and indirect. The direct waste is simpler and less hurtful, as the needless energy expended by the muscles of an arm exerted to raise a weight in such a fashion that twice the power is put forth required to perform a task. Indirect extravagance of energy is a far too common habit (for habit it becomes whatever the original impulse) by which tension is maintained in more muscles than are concerned in the performance of an act, whereby a prodigality of nervous force is expended. Again between the performance of all muscular acts, there should be periods of complete relaxation of tension, by which alone prompt repair is secured. Back of and controlling all this is the emotional balance whereby the nervous energy is made to act to an undue prolongation, or to a squandering of the cellular consumption. Thus it is that two persons, or the same person on different occasions, set forth to do a bit of work requiring precisely the same effort. One

will by economy accomplish the full result and not be fatigued—the other works excessively and is wearied. The first is the better for the doing—the second feels exhausted at the end. The nervous system is in continual education from the cradle to the tomb. It is better to maintain constant and accurate though economic functionation. Overuse, or worse, disuse, results in dimming the lamp of life, and the consequence is a marring of the elements of beauty. Complete relaxation or poise is the starting point of all effort.

The most important ground for possible safeguarding and prolonging of human comeliness is by means of securing and maintaining full elasticity of all the tissues. Old age may be described from the standpoint of physiology, as the period of hardening of the structures; it is one of development, not necessarily of decay. This is both inevitable, a normal change, and also there are many threatening exigencies standing ever ready to carry it over to the realm of disease.* The prevention, as well as the cure, lies in the deliberate, accurate employment of normal movements. If the activities have been habitually of an objectionable sort, monotonous in character as from labors limited in scope or from choice, or inadequate in variety and character, the tissues acquire stiffness sooner than they should. If the individual has never acquired full symmetric development of muscles, as is true of the large majority, these changes will appear earlier, and become more conspicuous. Again, full muscular balance and competence is conditional upon a certain degree of intelligent direction and impulse. Sensations exist for the specific purpose of inciting us to action, either immediate or remote. If they fail to initiate the proper actions their failure is absolute. Brain exercise of all kinds is accompanied with motor elements; no force is lost. If the associative fibers in the brain are inadequately developed by use and training there must be a deficiency both in motor and in sensory areas. If the early sensory promptings are insufficient in kind and variety there must result inferior human machines. Action of all kinds, mental and muscular, conditioning both efficiency and grace, can only exist in proportion to the power and variety of the stimuli and responsiveness of the centers. Action is the result of memory images, the outcome of sensory promptings. It is efficient if encouraged and is not if these stimuli are neglected or suppressed.

Old age is too often looked upon by those who have reached it as an evil fate to be resented or bewailed. Without combating this view from the standpoint of philosophy, let us reflect rather upon the many instances of beautiful old age which it has been our privilege to know. Is not this picture of well spent years familiar? "She was a wonderful creature with bloom and color, endowed with an intensity,

* See THE POPULAR SCIENCE MONTHLY, March, 1904, article by author—subtitle 'Physiology of Decadence.'

a mobile charm, which breathed of forces long maturing and almost perfect. She regarded life from a standpoint of abundant humor but never to the detriment of highest ideals."

In man old age is admittedly a crowning of honors won and esteem earned. It remains for him to secure or lose this reward. Fate rules, it may be, but his rulings can be potently modified by him who wills and acts. To woman advancing years come as the sealing of a well, if she has eyes only for the surface of things, and is blind to the warmth and life of the under-currents whose power is oftener overlooked than weakened. It is far more a question of what manner of woman she was, or has become, than of age or appearance as judged by the critical. If she feels tempted to grow slovenly in the niceties of pose and expression or in her dress, let her check this as a sin: for sin it is, and an offence against God and his good gifts. Women of three, or even four, score years have reigned queens in society. Many prefer a smaller kingdom, content with modest spheres of influence; but let them exercise care as to the line and direction of ambitions and be sure of their fitness to fill the niche of their choice. Once chosen it is a simple equation between vigilance and tact, rather than between the inherent worth of their charms and the fusing points of their subjects.

If hints are needed how to attain exalted posts of honor or ornament, here are some modest ones. Interest in the doings of her fellows, exhibited judiciously; a capacity to listen with an air of real interest to the fountains of speech artfully loosed; a clarity of mind on matters of the day, private and public; a gentle dignity coupled with what we may call graciousness; these will carry a woman miles beyond another in the esteem of her fellows who, making light of these gifts, yet possesses much intellect, endless accomplishments and striking physical beauty. If a woman tends to become giddy or frivolous, especially in her later years, so soon as she realizes this ruinous bias let her quell it or seek a cloister without delay. If she acquires, moreover, a manner of condescension or patronage, she may attune her mind to move thereafter much alone.

It may be said by any one who has read so far, that generalities may incite to reflection, but specific directions are required to demonstrate how each one may attain that grace and elasticity which is the very basis of original, and much more so of retained, comeliness. Beauty may be given to a few, and fewer are able to hold it without effort beyond the ordinary period when it tends to fade. It is a plain physiologic fact that comeliness may be enormously enhanced, but it is necessary that intelligent effort be exerted to secure a continuance of this endowment. Again, a person may possess many, or enough, of the elements of beauty and yet so abuse these gifts by omitting to

exercise a self-respecting care that their physical attractiveness may never exert the influence which in duty bound it should. The possessor of beauty is, to quote the immortal Bunthorne, 'a trustee' with responsibilities definite and grave. To ignore these, to suffer them to fall into neglect, is a misdemeanor in young or old.

Beauty may be marred by factors both psychic and physical. Physical deteriorations are of wide variety, some preventable and others inevitable. Where disease steps in it should be philosophically endured, but only up to a certain point, because even here apparent destiny need not be accepted as final. Disease is sin, hence preventable in great measure and remediable in a large degree. The greatest peril is from listlessness, self-indulgence or indifference, or, worst of all, from unwise meddlesome advice.

Can beauty then be increased by effort? Yes, and to a conspicuous degree. Can good looks be retained as age advances to, or beyond, middle life? Decidedly much can be done, even for those who in earlier years had little or none, and be made to remain with one till death. This is practicable, too, by the expenditure of only a moderate degree of time and pertinacity. The *sine qua non,* however, is a sincere and zealous desire for results. No tepid willingness will suffice. The arrogant woman or man who condescendingly submits to such measures as shall be outlined here, but fails to supplement them by earnest cooperation, should use time and strength otherwise. There must be an investment of hours and energy, and above all of intelligence. Along with this must be assumed a submission to some slight bodily discomforts, at least at first; by and by the means employed become a positive and unfailing source of pleasure and comfort and there soon arises an increased and sustained capacity for enjoyment and usefulness.

It is possible only to speak in general terms in so brief an article and to enunciate merely fundamental principles. These can be amplified in proportion to the wisdom and vigilance of each. They are best first taught in outline by experts and later can be systematized and pursued alone. The line of action should involve a clear notion of bodily hygiene, food, rest, sleep, bathings, care of the skin, teeth, hair, outings, clothing, etc. Every one may think he or she knows enough about each and all of these points, but will find that there is yet much to be learned if the subject is approached with an open mind. A great deal that is currently accepted on physical fitness is wofully archaic, and yet ample knowledge exists for those who search diligently. Recognized authorities are too often palpably ignorant in some important quarter, and all the dicta of teachers should be critically weighed in the light of advancing physiology, and only their tenets accepted if genuinely sound.

The one central thought which I wish to emphasize is the paramount principle that beauty of form depends upon accurate adjustments of the skeletal structures along with the fullest possible elasticity of the tissues. Perfect equipoise assumes elasticity of muscles and complete mobility of ligaments and tendons consonant with their functions along with capacity for fullest relaxation. Further, as age advances and disease or mal-use exerts its deforming effects, undue pressure is placed upon vital structures such as blood vessels and nerves, and innervation and circulation are interfered with, less or more, until as middle life passes and plasticity subsides, various noble tissues are impaired and vital organs suffer functional limitations. For instance, the eye, the ear, the brain thus fail to maintain perfect nutrition, and acuity of vision, hearing and cerebration lessen steadily, unless the tissues of the neck are kept free from rigidities. The fact is obvious enough and capable of easy demonstration, that the more elastic person enjoys fuller organic competence than one whose tissues are dense or rigid.

Density is bad enough, for reasons cited, but it is worse if deformity is added. For thereby is not only the caliber of blood vessels and nerve fibers, tendon sheaths, structures of the thorax, etc., compressed, but the lungs, because of thoracic incompetence, become incapable of exerting their full duty in oxygenation, and the power of the great oxygenating grounds, the muscles, begins to wane. Ugliness inevitably follows, not confined to shapelessness and warping, but color suffers, not only of skin or hair, but congestions or lividities are shown upon eyes, lips and nose. Nothing so centralizes the esthetic effect as the condition of the eyes; if these are clear and bright much else is overlooked.

Again, inadequate oxygenation and lymphatic stasis are correlated. Mere bulkiness is not displeasing to the eye, and many fat people are exceedingly handsome, often graceful, and exhibit most agreeable lines and color. A far more uncomely appearance is produced by the unhealthy thickening of tissues, only too common, occurring about the waist line from lymphatic stasis in those otherwise not overnourished. This water-logged condition often indicates grave departures from health and is capable of much amelioration, oftentimes it can be entirely removed, and always with advantage to health as well as to appearance. Free exercises will not accomplish so much as elasticizing movements judiciously increased, full passive stretchings, readjustments and full accurate breathing. It is true that violent and prolonged gymnastic performances will do a good deal, but these are often not feasible, or are distasteful, and the intelligent employment of personally directed exact movements can always be most safely relied on. The one essential principle is accuracy, with increased forcefulness to the limit of tension, with intervening periods of complete relaxation.

If medical men knew more of the subject of the physiology of bodily esthetics, they would be preeminently the ones to give counsel. Physicians know, however, almost nothing of the science of physical economics and leave this whole most important department of improving physical efficiency to those who teach for hire. They occasionally recommend loosely that those under their care shall take physical culture, but they would be sorely puzzled to differentiate between good and bad instruction. This is almost as true for those who have been, in their day, more or less athletic themselves as for the contentedly sedentary. Hence when the assertion is made that it is among the most exalted duties of the physician to give specific advice in this line, many will brand the statement as absurd. Nevertheless, the physician is the one who by his scientific training should be best able to point out the faults of posture, the defective quality of tissues, why they are not fulfilling their functions properly, and precisely how they can be made to do so. The consequence is, now that physical culture is so popular, all manner of blatant ignorant folk are posing as instructors and specialists in improving the body, and much harm is often thus caused, sometimes unrecognized till long after. Yet so much good is often thus effected that people are disposed to welcome these ignoramuses as prophets of wisdom and abide by their advice rather than seek counsel of legitimate educated conservators of health. Nevertheless, the fad of physical culture is distinctly to be welcomed with all its present limitations and even its perils. It will leave a valuable impress on the period. In due time the medical profession will give it their attention, and competent expert advice can be expected from them.

Let me make a few suggestions, from the standpoint of a medical man long and practically interested in this subject, to those who desire to preserve their looks and by so doing their health; for the terms are in effect interchangeable. As has been said, this essay is directed chiefly to the conservation of elasticity, poise, movements and graceful contours. Much can be accomplished by free movements, plays, games, both indoor and outdoor, but among those who are brilliant exponents of all these pastimes will be found many very awkward in action and faulty in poise, who are sufficiently well formed and of skilful and accurate coordination. Some such persons, even of advanced years, have been trained by the writer to move and appear to vastly greater advantage by pointing out the key-note defect and showing just how this may be overcome. For illustration, take the position of the torso in one who stoops or droops. This may be only a bad habit of holding the head, yet if this alone is corrected without having the attention called to the correct position of the neck on the chest, or the balance of the shoulder blades and the tonicity of the erector spinæ muscles, etc.,

erectness of the head may appear merely stilted and arrogant, and little is gained.

To tell a person of slouching figure, stiffened by advancing age, warped by ligaments in faulty poise, to stand up straight and throw back the shoulders, etc., will accomplish little or no good. It is necessary to point out specific faults of structure, correct weakened or contractured tissues, to teach just what precise movements can strengthen the one and elasticize the other. Where contractures are noted (and they are always present, less or more) the parts must be sedulously overstretched. This will be somewhat painful, but only at first. For daily or bi-weekly systematic teaching a skilled masseur or physical trainer can and will take more time and give more constant attention than the physician could afford, but it is impossible to expect these trainers to estimate individual needs scientifically or carefully, especially as progress must be made, if at all, in a consistent direction. Movements for acquiring elasticity should by no means be confined to the limbs; the largest gains are to be secured in the deeper structures of the thorax, shoulders, back and loins. Here the expert eye of an anatomist is needed. Even more so in those most important structures of all, the abdominal organs. Large knowledge and experience are required to permit or encourage accurate adjustments of these parts. All movements, active or passive, of an educational character, should be made with the utmost accuracy of direction, or they fail in some measure of utility. Furthermore, a fundamental principle is to make each movement with increasing forcefulness, till at the end of the act the fullest tension is secured. In this way alone can strength, elasticity and full coordinative power be attained.

Time also is a potent factor, along with persistence. There is always more or less rigidity to be overcome in the tissues, often unrecognized minor deformities and limitations which mar both attitude and freedom of action. It has taken the writer years to rid himself of some such rigidities, and most folk are similarly circumstanced. Especially is this true of the thorax, which, even in late middle life or advanced age, is yet capable of large emendation and increased efficiency well worth the effort. Much indeed can be effected here by right breathing accurately taught; full forcible inspiration followed by complete expiratory expulsion, always with careful rhythm and judicious variations in rate.

It must be remembered that voluntary movements of the muscles are always valuable and often necessary to maintain the powers of oxygenation by which cellular interchanges are carried on, so that nutrition may progress, the organs kept to their normal activity and restful sleep obtained. It is possible that the nutritive balance may continue more or less well in some people under certain circumstances and for

a long time with very little bodily activity, but the omission is a grave peril.

This capacity for passive circulatory equipoise varies widely, but can not be relied upon to carry any one far unless supplemented by a moderate amount of voluntary action. Some folk claim to obtain enough physical stimulus from mental activity, especially when energetically directed, to suffice for their apparent needs. By intense cerebral energizing undoubtedly metabolism is stimulated, more food demanded and waste disposed of, than when thought is lowered to musings. Some can do with active conversations and laughing. Also music acts wholesomely in the same way. Hence it is compatible with fair health to live a sedentary life, but only if the circumstances of life be, and remain, uniform and wholesome, and the bodily functions so symmetrically carried on that no great strains come and no nutritive nor degenerative disorders arise.

For all, young and old, it is important, in order that full mental and physical health be maintained, that systematized bodily activities shall be practised with some regularity. From this conclusion there is no escape save by self-deception. Assuming then that we have a perfectly normal body upon which to reckon influences for good or evil, we will proceed to analyze the effect of voluntary movement. If a person is entirely oblivious to his own consciousness, that is, entirely free from hyperconsciousness, movements will be made easily and in accordance with instinctive impulses. If the mechanism be perfect or nearly so, the movements made in the ordinary activities of daily life will be entirely natural and consistent with the special structure and abilities of the individual. Provided also that the opportunities for these movements be natural, and sufficiently varied, and if there be adequate stimulus to move, and continue to move, throughout the ordinary exigencies of a working day, and further, if nothing interferes with the normality of these movements, the result should be perfect action and development.

It rarely happens, however, that such a status is maintained. Several influences creep in more or less forcefully to interfere with the symmetry and naturalness of bodily movements. The first factors which should be reckoned with in altering the symmetry of the body are minor inherent defects of development in the skeletal structures by which a tendency is early established for the stronger side to overwork the weaker one. This will be better understood in the brief anatomical description which will be given later. The second thing is dress. In proportion as dress exercises undue pressure on one or another part, it is capable of modifying structure and altering growth. What these influences are we shall mention in detail later. Next such influences as environment, habits, fashion and energy or indolence

largely deviate shape and carriage. Lack of variety in movements due to repetition of laborious acts exerts a modifying influence, usually for harm. It is not the effects of fatigue on the entire organism, but rather continued repetitions of movements by which the one part most exercised adjusts itself along the lines of least resistance to do its work most comfortably, which produces a warping of the unused complemental part. And finally the most potent agency of all in producing awkwardness and tension is exaggerated hyperconsciousness.

By far the largest proportion of those peculiarities of gait and carriage which are noticed in almost every one, although they may begin primarily in some structural peculiarity and are modified by dress and occupation, nevertheless are exaggerated enormously by this over-consciousness which affects somewhat every one. It will be plain to those who will reflect for a moment how differently they will walk and act in the privacy of their own rooms or among their families and friends from that which they will present if called upon to exhibit themselves in some public position. Let any one remember the time when first called to walk the floor of a crowded room while for a moment the cynosure of a large number of watchful and presumably critical eyes. Here the hyperconsciousness may become so marked as to produce in some a mental agony, which will be vividly reflected as a rule in suppressed writhings or contortions. This effect upon the body may not be outwardly shown to any marked extent, but an irregularity of tension is produced in the various parts which distinctly mars their natural ease of action or attitude.

Many of the deformities which come upon women are not recognized by them as such, and yet to the critical eye they are departures from the normal lines of development, and the results of habitually faulty attitudes, not present in youth. They need not have been acquired except through the artificial restraints of custom and a desire to conform to conventional poses. Such are the stiff or awkward and certain hyperconscious positions assumed by a lady when arrayed for display in public; witness the indrawn elbows, the contractured hands, either clutching a portion of her dress or a pocketbook, or both. It is apparently against the canons of taste to permit any freedom of motion, either at elbow or at shoulder. The gait becomes a constrained strut, because it is practically impossible to allow the thighs to move with naturalness and ease. In mobile adolescents, this is not so offensive to the observer, but as age creeps on and youthful elasticity is gratuitously sacrificed, as well as rapidly lost from senile changes added to disuse, the picture presented of an elderly woman parading the thoroughfares is too often a repulsive one. On the other hand, if she ceases striving to make a good appearance and abandons herself to indolent attitudes, to droop and slouch, the spectacle is even worse. This unfor-

tunate state need not arise, if, as a girl, the woman becomes acutely alive to the value of retaining grace (which is entirely practicable), provided nature has endowed her with fairly symmetrical bodily proportions along with accurate instincts as to attitudes (all too rare a gift). More to be welcomed, because thoroughly acquirable by any one, is a wholesome guidance of the growing body and wise instruction in the right standards of breathing, standing and moving. There is an eminently practical value in avoiding this state of acquired awkwardness, which has a direct and important bearing upon health and longevity. It may be permitted to again direct attention to the derangements which follow upon constrained attitudes, habitually maintained, in compressing the chest, hence the lungs, heart and the great organs, and particularly because of the less obvious, but equal, peril from constriction of important arteries, veins and nerve trunks. It is difficult to convey to the lay mind the gravity of posture deformities, practically the same condition as occupation and costume deformities; the differences being merely of causation and degree. It is quite comprehensible how grave an effect is wrought upon the morphology of the organs, for example, in a miner who assumes various unnatural attitudes demanded by his work, in nooks and crannies of rock. Here he lies or stoops for hours at a stretch, digging laboriously, and in time becomes grossly misshapen. Still he is in constant action and the elasticity of the tissues is not lost so early as in many other occupations where constrained positions are maintained with little change and only such movement demanded as is limited in scope, monotonous and exhausting by endless repetitions. The song of the shirt has brought some phases of the subject to the public attention. Let any one visit large manufactories and he will acquire a vivid object lesson. It will be perhaps more clear to call attention to the deformities of neglect. Unless a child has enjoyed the fullest opportunities for spontaneous activities, numberless small abnormalities will arise and become emphasized. Observe any group of school children critically and there will be readily noted posture deformities in most of them well established and liable to become fixed and exaggerated in later life.

A strong argument for employing a wide variety of bodily movements can be drawn from the fact that man being the only upright mammal, many of his organs assume and are maintained in positions and relationships foreign to their original adaptation. Ages and generations of characteristics acquired in the upright attitude have given him large control over these organs and their supporting tissues have developed admirable adjustments adequate to all ordinary needs and under ordinary requirements. Among the requirements for healthy organic structures is always exercise or use whereby alone function is conserved and organs maintained in normal position and condition.

These exercises should be along the normal functional lines, not out of them, but keeping in view the fullest range of customary movements, many of which become impaired and almost lost from lack of accurate use even in young persons. First of all, bear in mind that nine tenths of ordinary movements of the arms are flexions, hence it is necessary, in order that one may become symmetrically developed to practise forceful, accurate extensions till complete extensor competence is attained. The movements of the legs are mostly extensions, hence in them flexions must be cultivated systematically.

In the motor areas of the brain there are probably two sets of cells coexisting alongside, one for flexions, and one for extensions. In the arm centers those for flexions are in constant use, hence well developed, and the extensor cells suffer degenerative change. In the center for the legs the reverse obtains. The neck and structures about the shoulder blades in man are little used in the ordinary demands of life, where few movements are called for, and hence are seldom brought into full action. These readily become rigid from disuse and fail to maintain symmetry. Yet in this region lie some of the most important subsidiary nerve centers. The effects of these rigidities by exerting pressure on nerves and blood vessels impair nervous mechanisms, and hence the nutrition of the organs of special sense in the head suffer. As these are removed dimness of vision grows less, hearing more acute, discomforts or pains in the head cease, and youthful capacities and *bienfaisance* are in great measure restored.

Unless these tissues are kept mobile, especially at the age when free activities are gradually abandoned, this region loses beauty rapidly and nowhere is the evidence of age more conspicuous.

Diet, already alluded to, exerts a most influential bearing on health, and hence comeliness. It is enough to offer here a brief summary of the guiding principles of dietetics which will suffice for all ordinary exigencies. A word must be said about the care of the teeth upon which often the whole proposition depends. Teeth receive good attention by nearly all civilized people to-day, yet we physicians are often amazed at the instances of neglect which fall under our observation. Many of these dental defects prove to be the chief factor in obscure conditions of deplorable ill health, even among people of wealth and refinement. This is especially true of disorders of the gums.

In order to maintain digestive competence, from intake to output, it makes far less difference what food is eaten, than the manner of taking, and the amounts consumed. In the choice of foods, a good rule for most people is to make a selection from those articles which are ordinarily accessible and eat with contentment and thankfulness, being guided by a purely natural appetite. Artificial environment and faulty upbringing tend to impair the sanity of taste and appetite, and

ill health may, and does, vitiate both. Instinctive desires are always present, if not obscured, and can be trusted.

Varying conditions of the body, fatigue, emotion, exercise, indolence and the like, make conditions which influence choice at a meal, both of articles and amounts, which demand obedience. Not one mouthful more than nature craves should be swallowed. Certain rules obtain as to times of eating, and sequences of dishes, to which we must conform, but it is entirely possible to do so with judicious selections and rejections. Age makes much difference in all this. In middle life, and later, a small amount of food will suffice for all requirements. The greatest safeguard lies in cultivating the tastes of earlier and simpler years, bearing in mind that in the period of full development we eat to maintain life with little need to develop structures, unless acute or prolonged illness has caused unusual destruction demanding repair. Forcing the appetite may be at times needful, but it is always a peril unless advised by a physician. When in doubt, go hungry for a day. Thus will the whole array of disorders of metabolism, gout, diabetes and the like be limited. Careful preparation of food is desirable, but superior cooking is secondary to many other considerations. Simplicity in preparation comes next to cleanliness, and soundness is of course to be assumed as necessary, particularly in articles of the more perishable sort. It is well to avoid adventitious aids to flavoring such as tricks of combination and overmuch condiments. These irritate the organs of perception and ultimately impair both digestive vigor and the sense of taste. By far the most important rule to observe is that all food shall be most deliberately masticated and each mouthful involuntarily swallowed before any more be taken into the mouth. This holds good for fluid foods, especially for milk.

Finally, one word as to fluids with meals. Digestion is a process of solution by hydration and about a glassful of water is needed at each meal. Fluids taken before or after meals are ordinarily permissible. If any is taken during the meal at least no partly masticated food should be in the mouth to be 'washed down.' If so it has not been sufficiently comminuted or insalivated, and does not enter the stomach in perfect condition for assimilation.

One word as to the effects of the corset. The use of the corset we may be compelled to accept as a feminine necessity, but if so it argues for the wearer a loss of normal tissue vigor much to be deplored. As an auxiliary to modern dress, which fashion dictates shall be close-fitting around the waist, we have little to say, but as a support to the abdominal structures, a remark is justified. There is no essential demand for artificial aid to sustain the abdominal organs, but if such need is felt to exist, it is, and can only be, due to consciousness of a structural defect. This has been demonstrated repeatedly in many

women, old and young, by educating the muscles of the waist till they were able to comfortably meet all demands, actual and artificial. If corsets are claimed to be required on esthetic grounds, the reply is, that among well-constructed women, whose tissues are normal and who have acquired and retained normal attitudes, no improvement can be made by empirically adapted mechanisms. This is proved by the universal admission of the fact that a young girl of good figure does not require corsets. A bust support or special waist can be used if demanded, but this should not be a confining, unyielding cuirass. Then it follows that those who insist that elaborate molding contrivances are imperative by the making of this demand, tacitly admit that they have become already deformed. The question must then be faced whether this deformity is the mark of fate, or is due to individual culpability. If the former be true, let them accept if they must the compulsion of machine-made figures to conform to the dictates of fashion. If acquired by faulty attitudes, lethargy or epicurism, or all three, let them set about recovering as from a disease. This is entirely possible, and only otherwise if the person is irresolute or ill-taught.

Again, there are long backs and short backs, with various degrees of space between the ribs and the pelvic bones. A woman with a long back and plenty of room between the thorax and the pelvis, can wear a corset with less danger, because the greatest hurt is from interference with the action of the lower parts of the lungs. It is a grievous sin against health to restrict the chief oxygen laboratory. For this oxygen interchange full muscular action alone will not suffice; free lung room is essential. A woman with a short back, but plenty of room between ribs and hips, may wear a low or narrow corset with small danger. When there is little soft tissue between these parts the ribs are readily prevented from full play. Then not only lung action is impaired, but liver, kidneys and stomach are all compressed and made to relax from their supporting tissues, and tend to fall down confusedly toward the bottom of the abdomen. Hence arises the long train of ills growing commoner daily in all corset-wearing countries: movable kidneys, livers, dropped stomachs and intestines, and above all displaced organs of generation. The chief damage from the corset is the circular compressing action exerted upon the blood vessels of the waist, whereby passive congestions are induced in all tissues, and the great organs are forced downward, aggravating the weakness of the already mechanically frail normal supports. The straight front corset is only a little less bad, since it presses inward constantly, and all continued pressure exerts paralyzing effects on vaso-motor nerves and muscles. The least harm is done by that form of corset which has as part of its action, a low-placed firm semi-elastic belt so adjusted as to hold up the contents of the abdomen from a level with the outer hip prominence, and thus prevents the downward pressure of the rigid waist-encircling garment.

ART IN INDUSTRY.

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The Significance of the Arts and Crafts Movement.

DURING the last century the productive powers of man were multiplied many times by the utilization of the energy of coal and water through the agency of steam and electricity. As a result the human race has been lifted from a condition of struggle for the necessities of life to a higher plane of material comfort. With the increase of material wealth has been ushered in the new spirit of democracy. Leisure, culture, education, art and work are now conceived to be the birthright of all. Universal education and culture has heretofore been impossible because of the meager productivity of the unaided man. The arts and crafts movement of to-day is democratic. It proclaims to the world that beauty, skill and education are for all; and that the common thing should be made beautiful, and the beautiful, universal. If the machine enables us to produce the necessities of life for all, it is, nevertheless, the skilled human hand which must adorn and beautify these products. The hand must find its province where the machine can not go. In its proper sphere, the machine may make beautiful things, and may even excel the hand; it is not the use of the machine, but the abuse of machine production, which should be deprecated; without the machine much of our present material comfort would be impossible.

Art is a form of industry, and industry properly applied always brings forth a work of art. The mechanic, fashioning the accurate and splendid tool, produces a work of art; the man, forming with infinite care the lenses of the great Lick telescope, brings into being another work of art. The automatic screw machine and the steam engine are as certainly works of art as the painting or the sculpture of the great masters of the Renaissance. There is and can be no real art considered entirely apart and distinct from industry and the industrial life of the people. As Emerson has said: "Beauty must come back to the useful arts and the distinction between the final and the useful arts be forgotten." Art is a way of doing things and resides in the common as well as in the uncommon, at home as well as abroad, in the present as well as in the past.

The old craftsmen were artists. They wrought with infinite care as much for the satisfaction of doing good and true work as for the money value of the product. The products of the craftsman's skill

were few, and only the ruling classes were privileged to possess them. The laboring masses were busily engaged in obtaining the bare necessities of life; no thought of comfort, art or education entered into their lives. The craftsman did unite art and industry; but the modern conception of democracy did not exist. On the other hand, the modern workman is only a link in a great industrial chain. He repeats, in a monotonous routine, certain simple movements; no realizing sense of the true social value or significance of the work which he performs ever comes to him. Long hours and routine work crush the individuality and ambition out of him.

The specialized worker necessarily has narrow views of life; his ability to enjoy is limited. The opportunity and privileges of both working and leisure hours are only partially utilized. It has been said that for a man of twenty, pleasure is business; of thirty, business is business; and of forty, business is pleasure. It might further be maintained that there is little pleasure outside of business for the ordinary man of forty or fifty. Business, the grind of daily life, has engrossed the entire energies of the man. Enjoyment in life means enjoyment of leisure and of work. The unskilled laborer, I fear, enjoys neither—why? His work is monotonous and wearing, the surroundings of home and workshop are not inspiring, and he has received no training which will aid him in finding and utilizing the few opportunities for rational enjoyment which come to him.

The present arts and crafts movement is a protest against and a reaction from the minute division of labor now employed in manufacture, and the stripping of the artistic features from industry. Articles are made to sell more particularly than to serve a useful and important service. Profit, not service, is now the watchword of industry. Art in the crafts would emphasize service. The arts and crafts movement aims to give dignity to the worker, and to teach that all should be workers. The man of leisure is a drone and a parasite. Each individual has some particular work for which he is best adapted; and society needs his services. Only when all are workers and each striving to do his best work does society approach an ideal condition.

The arts and crafts movement needs educated producers and consumers. The task is a double one; the workers must be trained to produce good work, and the taste of all consumers must be educated so that they will demand good articles. Shorter hours and the right use of leisure will give an impetus to the demand for better qualities of goods; and thus variety and handicraftsmanship will to some extent replace interchangeability and machine production. All civilized men demand the necessities of life—food, clothing and shelter—of a character not greatly dissimilar; these common requirements lend themselves readily to machine production. Industrial operations in which machinery is the chief factor are directed toward producing the

greatest possible quantity of a uniform quality; therefore, as far as inventive skill will allow, the machine and natural forces, rather than human skill and energy, are employed in producing goods which satisfy the common needs of all men. The class of work in which skill is the determining factor aims to improve the quality rather than to increase the quantity produced. As the demand for the latter class of goods increases the call for skilled workers will also increase.

There are indications of a revival of those industries involving more skilful hand work. More interest is being manifested, throughout the country, in art, architecture and the products of the various handicrafts. The increased attention paid to art and drawing in our public schools is another indication of the coming change in the spirit and demands of the American people. The result of such training on the next generation will be great, and its effect cumulative on the succeeding one. Industries involving artistic ability and intricate manual skill are incapable of minute division of labor. The gain resulting from the centralization of industry and the division of labor is very small in this class of work. It is well adapted, however, to small factories and workshops, and forms an appropriate kind of industry for small villages. If there is to be any considerable revival of village industry, it must come through an increase in the demand for the products of skilled manual work.

The use of steam and the lack of adequate rural transportation facilities forced the abandonment of village industry and built up the existing great industrial centers. In recent years the increasing use of electricity for the distribution and application of power is changing the location and internal arrangement of our shops. This, together with the rapid growth of suburban and interurban electric lines, is placing the villages and rural community in a better condition for industrial pursuits. The separation of agriculture and manufacture will, as a result, probably be less in the future than in the present or the immediate past.

Two great forces, in addition to the work of the school, may be discerned to be removing the obstacles in the path of the arts and crafts movement—the decentralizing tendency of electricity when used to transmit power, and the growth of the labor movement which demands shorter hours and better shop conditions. Just as the manual training movement was a result of economic and industrial changes, so is the call for art in the crafts the result of such forces. As the machine displaces workers, they are pushed higher up in the industrial scale. Such a phenomenon must also be accompanied by an increased demand for the products of skilled workers. This movement is not something evolved out of the minds of a few thoughtful devotees of art; but is in harmony with and dependent upon the needs of industrial and educational life. It is an evolutionary movement.

SOME PLANTS WHICH ENTRAP INSECTS.

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WE seldom give a thought to the fact that plants need food. They lead such mute, motionless lives that it is difficult to believe that they have, like ourselves, a bread-and-butter problem staring them constantly in the face. We watch the geraniums and begonias of our window-garden grow and bloom with nothing to nourish them but a few handfuls of earth and a little water. Surely their food problem must be a simple one if the substances necessary to the formation of stem and leaves and blossom can all be got from so little earth. Wherein lies all the difficulty about poor soil which besets the farmer, and why must he buy tons of plant food and drill it carefully into the ground in order to get a remunerative crop of grain? The whole trouble for the farmer arises from the scarcity in the soil of two or three food elements which, although highly important, form but a small part of the total weight of growing plants. The foremost of these scarcer foods, nitrogen, has been a source of difficulty not only to man, but to a large number of plants as well, which have been forced to adopt a means of getting it which is radically different from all other methods of plant nutrition, so much so indeed that it was long looked upon as a mere meaningless 'freak of nature.' This method is the catching of insects.

Every one has heard of the pitcher-plant or perhaps seen its urn-like leaves half filled with water. Innocent looking as are these leaf-pitchers, and casual as may seem the presence of three or four drowned flies in the water which they contain, yet in truth each pitcher is a veritable trap, clever in design and effective in its purpose of alluring and drowning insects. Different in look, but to the same purpose, are the leaves of the sun-dew. Its bristling hairs bear beads of jelly, not for the mere splendor of their dazzling brilliance, but to allure, catch and hold fast gnats and mosquitoes, all to the same end as in the pitcher-plant,—supplying a shortage of nitrogen in the food. Not these two plants alone, but a large group of nearly four hundred species, are insect trappers, carnivorous or, as they are more commonly called, insectivorous plants. The varied devices which these plants possess for alluring insect prey, catching, holding and utilizing it furnish matter for one of the most interesting chapters in all botanical science.

Perhaps no one of the insectivorous plants possesses what may be more truly called a trap than does the bladderwort (*Utricularia*). This is a floating aquatic plant without roots, confined to pools and quiet streams where it is in no danger of being washed away. Borne thickly upon the fine leaves, and like them entirely submerged in the

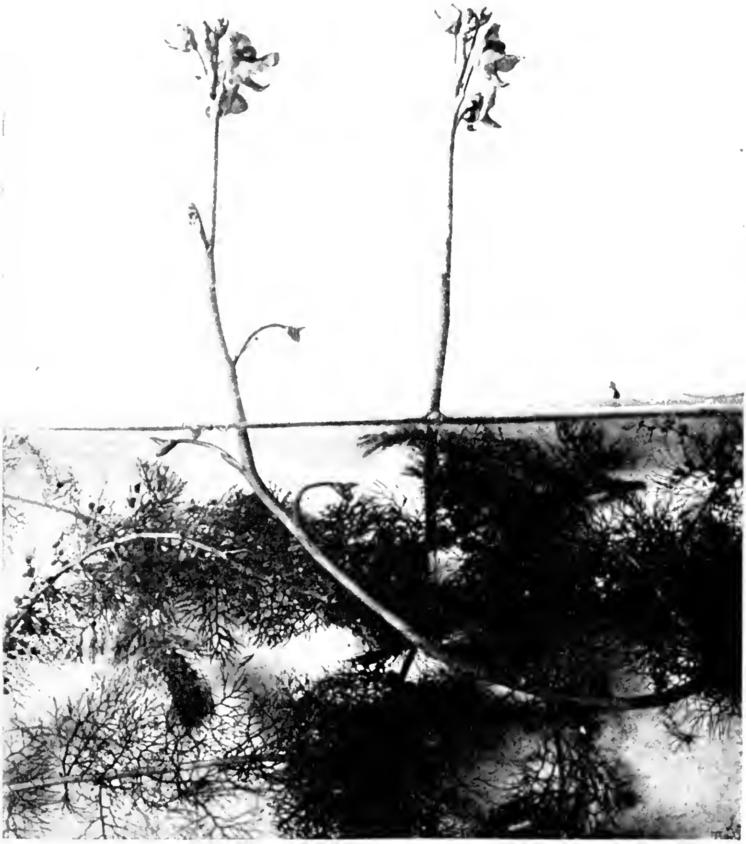


Fig. 1. THE BLADDERWORT IN BLOOM. At the left may be seen the traps.

water, are the traps, minute hollow globular structures bristling with hairs at one end. Buried among the hairs is the entrance to the trap. Swimming about in search of food or in an attempt to escape from enemies, some minute crustacean or insect larva will push in among the hairs. Spying the entrance, it will dart forward and striking the almost transparent door it will unwittingly pass into the trap. But the door has instantly sprung shut again and vain will be all the efforts of the prisoner to make an escape. Starvation soon ends its struggles.

death is followed by decomposition, and in the absorption of the products of this the plant accomplishes the end for which it possesses the traps—it gets its needed nitrogen.

In the pitcher-plants the urns of water are set and all else is left to the curiosity of the insects, the inner structure of the leaf being such—as we shall soon see—that a secure trap-door is not needed. The half dozen species of pitcher-plant (*Sarracenia*) exhibit considerable variety in the form of their leaves. In the purple species, the only one growing north of Virginia, the leaves form a rosette-like cluster procumbent on the mud or moss and bent upward so as to give the mouth a horizontal position. The stalk is exceedingly short and the leaves, heavy with water, never rise above the surface of the swamps and bogs which are the only home of the plant. At blooming time a stalk is sent upward for a foot or more, bearing the curious leathery flowers which nod to one side in a manner which has led some one of vivid imagination to call this the 'side-saddle plant.' The water which fills all but the youngest of the leaves is simply rain-water which has fallen in, and has nothing to do with the water supply of the plant in the ordinary sense. In the water are pretty sure to be some struggling insects trying to float or to crawl up the sides of the pitcher, some others whose struggles are over, and the remaining legs and wings of still earlier victims. All sorts of flying and creeping things seem to have a natural curiosity to examine hollow caverns such as the pitchered leaves appear to them. Perhaps, too, they are drawn to the plant by its rich red coloration or the striking veins which mark the mouth of the pitcher; indeed, one botanist has found drops of honey arranged in a row up the side of the pitcher, a lure to guide the steps of the insect directly to the interior. The wing which runs up one side has been thought, too, to serve a use in preventing insects from crawling round and round the pitcher, and to direct their steps upward to the slippery edge of the mouth. Once falling from the edge into the water, slim indeed, is the chance that any but the most active of insects will get out. The sides of the interior are not only steep, but are exceedingly smooth and offer no foothold by which to regain the top. And even if the bedraggled creature should succeed in crawling up beyond the slippery zone it would encounter an array of long stout hairs crowded close together and pointing downward. Over this ambush none but the most long-legged of insects can crawl, and

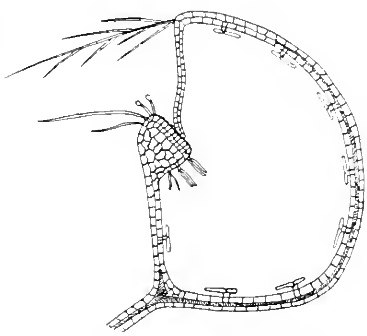


Fig. 2. A Longitudinal Section of a Bladderwort Trap greatly enlarged, showing the Hairs, the Mouth and the Trap-door

they are the very ones least likely to have ever got up the slippery zone. Wet and exhausted, they fall again into the water, where they soon drown and yield up the substances of the body to be absorbed by fine hairs lining the bottom of the cup, and given over to the nourishment of their passive captor.

Some of the southern species of pitcher-plant have leaves standing erect as much as two or three feet in height and furnished with a lid-

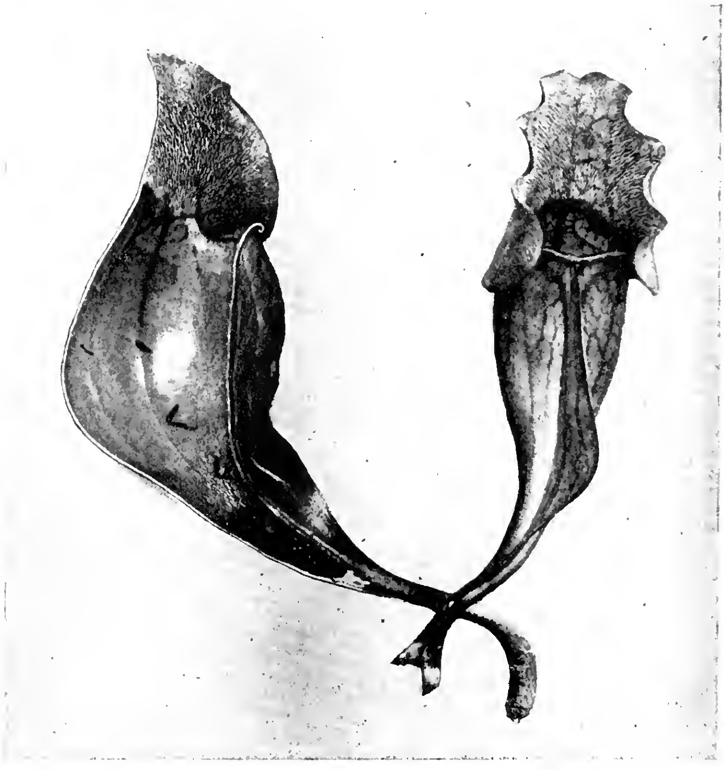


Fig. 3. LEAVES OF THE PURPLE PITCHER-PLANT. The one at the left is cut in half to show the interior, with the downpointing hairs at the top, the slippery zone (betrayed by the highlight), the absorbing hairs at the bottom, and the dark mass of insect remains.

like covering, not indeed a trap-door to shut down over the mouth, but serving to keep the rain from completely filling the pitchers and breaking them down with its weight, a provision which the purple pitcher-plant does not miss because of the prostrate position natural to its leaves. In other species the leaf is furnished with a hood arched over the mouth so as almost to conceal it, brightly colored with yellow or red, or marked with translucent spots. In the Californian pitcher-plant (*Darlingtonia*), a rare and local species, the leaf is hooded and the entrance small, but accompanied by a hanging pro-

jection shaped like the tail of a fish. The hood is marked opposite the mouth by a number of translucent spots which some botanist has imagined are false windows, against which entrapped flies bump their heads in a wild effort to escape, being thus diverted from the real opening!

In the swamps and along the streams of the rich tropical forests of Borneo, Java and Ceylon are found the East Indian pitcher-plants (*Nepenthes*), a group in many ways more highly developed than their American relatives, for there are forty species of them, all plants growing to a considerable size and several of them forming important constituents of the vegetation. The stem is erect or half-climbing, with long narrow leaves tapering to slender ends, which will twine like a tendril about any supporting twig or stick and then give rise to a single pitcher, or failing to find a support, will fail too to produce the pitcher. In variety of design, brilliance of color and showy contrast of spots and stripes the East Indian pitchers far outdo those of the American plants. They are provided too with elaborate lids and covers which here have a double meaning, for the pitcher is not filled with rain-water, but with a secreted water of its own, which must not be diluted by the rain, as it contains precious substances given out with the water from glands in the bottom of the pitcher. The most important of these substances is a digestive principle much resembling the pancreatic juice of the human stomach; and scarcely less important is a faint trace of hydrochloric acid, without the presence of which the digestive juice can not work, for it is not here for any idle purpose, but for the business of digesting quickly the abundant prey which tropical insect life affords. A fly which falls into a glass of water is often able to escape because the close-set hairs covering its body do not permit it to become thoroughly wet. In the liquid of the pitchers is another substance known as azerin, the property of which is to cause any hairy surface to become quickly wet, which means for the fly sure drowning.

Fig. 4. DRUMMOND'S PITCHER-PLANT OF THE SOUTH, WITH ITS COVERING LID AND SHOWY MARKING.

Here are pitfalls, then, not very unlike those of the American pitcher-plant in their mode of decoying victims and preventing their escape, but far advanced over them in their action, for the digestive juice yields up the nourishing substance of the insect much more rapidly than does the process of decay, and far more economically too, thus increasing the amount of the plant's food, and thereby its abilities for growth and reproduction.

The closed trap and the pitchered leaf are not the only devices for insect capture which we find among plants; they also possess devices which man has closely paralleled in his invention of fly-paper. These

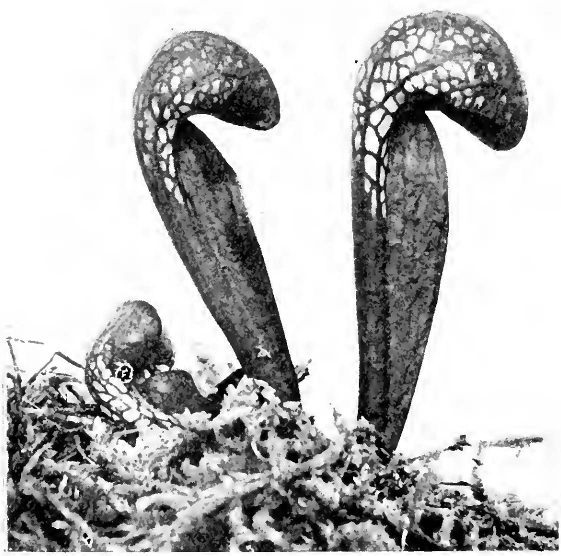


Fig. 5. LEAVES OF THE PARROT'S-BEAK PITCHER PLANT, WITH ITS HIDDEN MOUTH. The coloration is white and red.

are, in general, sticky secretions borne either upon a flat leaf surface or on the ends of hairs arising from leaves. The plants possessing snares of this sort are more numerous than those with pitchers, and quite as successful as the latter in obtaining a generous supply of nitrogenous food.

Simplest of this class of the insectivorous plants is the butterwort (*Pinguicula*), a small annual, not unlike some of our commonest violets in appearance. A dweller in high mountains and the cold bogs of the north, it is particularly well known to every one who has climbed

about in the Alps. The leaves are broad and undivided, slightly inrolled at the edges and coated on the upper surface with a sticky slime exuded from minute groups of glandular cells. An insect alighting on the leaf is caught and held by the sticky secretion, and the more it struggles to escape the more firmly is it held and the more completely does its whole body become involved. If the insect has chanced to alight near the edge of the leaf the inrolled margin will roll still

Fig. 6. FLOWER OF THE PARROT'S-BEAK PITCHER-PLANT.

further so as to cover it completely, but whether near the edge or not, there is something in the contact of this available food which causes the excretion of juice to be so abundantly renewed as to be sure to envelop the insect. In the renewed excretion there is to be found a digestive princi le such as occurs in the pitchers of the East Indian pitcher-plant, so the captured prey, soon smothered to death, is also rapidly consumed and its essence carried into the leaves by means of the glandular secreting cells.

It is of interest that the only case in which any of the insectivorous plants have been found of practical use is in connection with the presence of the digestive juice in the butterwort. There is associated

with it here, as in the stomachs of animals, a coagulating principle, a rennet. In some manner difficult to guess the shepherds of the Alps learned years ago that the leaf of the butterwort placed in fresh milk would cause it to thicken rapidly, and to this day they use these leaves rather than the animal extract in the making of curd for cheese.

Fig. 7. The Californian Pitcher plant. The white spots are the false windows, and in the head to the left, which has been torn open, may be seen the mouth, situated just behind the hanging appendage.

The sun-dew (*Drosera*) is one of the best known of the insectivorous plants of this class, both because of the wide distribution of the ninety species over the world and on account of the detailed and patient study of it which was made by Darwin, whose book 'Insectivorous Plants' is a rich mine of information for any one interested in

this subject. Our commonest sun-dew in the eastern United States (*Drosera rotundifolia*) is a delicate little plant without stem—a mere rosette of long-stalked leaves with rounded blades. Bristling from the upper surface of the leaf stand thirty or forty stout hairs nearly as long as the diameter of the leaf. At the end of each hair is a swollen gland surrounded by a globule of viscid jelly, the whole scarcely as large as a pinhead. There are few more beautiful objects in the

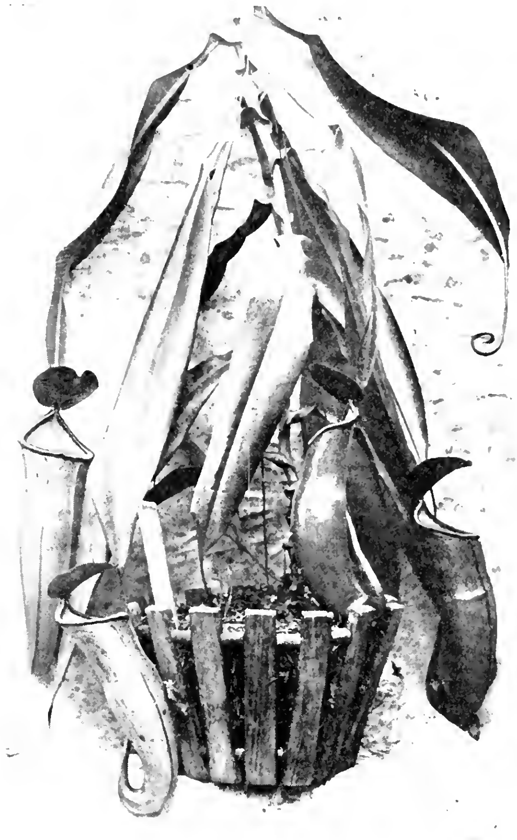


FIG. 8. THE EAST INDIAN PITCHER-PLANT.

plant world than a leaf of the sun-dew with its clear beads of jelly flashing in the sunlight against a rich setting of green and red. This splendid sight lures the small gnat or fly into contact with one or more of the beads and gives the jelly a tenacious hold on some particular leg or wing. The contact causes a disturbance to be set up in the leaf which brings the other hairs to bend towards the ones which have secured prey. If the insect caught is a minute one only a few of the hairs will be aggregated in this manner, but if a larger

one has become entangled all the hairs will take part in the movement, and even the blade of the leaf may be bent together in such a way as to aid in the aggregation of the tips. The globules of jelly fuse into a mass about the insect and there is poured out from the glands a digestive juice such as that in the East Indian pitcher-plant and the butterwort. All the soft parts of the insect are digested and the nutritive juices, rich in nitrogen, are absorbed by the very same glands which secreted the digestive juice.

It is obvious that the aggregation of the hairs causes a more complete surrounding of the insect with jelly, increases the amount of digestive juice brought to act upon it, and also the number of channels for conducting the juices back into the leaf. The movements here involved are comparatively rapid —the hairs nearest the one which has made a capture begin to move in five seconds; if the capture is a big one all the hairs will be aggregated about it in half an hour. The time required for the digestion of prey depends entirely upon its size and nature; when completed the jelly dries off from the glands, the hard indigestible parts of the insect blow away, and the hairs resume their usual positions. The globules of jelly are then renewed and the leaf is ready for another capture. A single leaf may partake of above one hundred such meals, but more commonly its life is shorter, its place being rapidly taken by a younger leaf.

Fig. 9. The Cup of Another Species of East Indian Pitcher-plant. Note the two directive wings on the outside and the ridge just inside the mouth.

These are highly complex structures with which we meet in the sun-dew, and the united action of the hairs in aggregating themselves towards the spot where an insect has alighted is an example of coordinated activity such as is rarely met with in the plant world. There are, however, no unusual structures here, there is nothing in any way resembling a nervous system and nothing suggesting any similarity to the coordinated movements of animals which they so closely resemble.

The most highly developed and remarkable of the insectivorous plants is the Venus' fly-trap (*Dionæa*), which will never cease to be the cardinal attraction with all florists so fortunate as to be able to

humor it into healthy activity. It is one of our rarest American plants, being found only in the bogs of a restricted area on the coast of North Carolina.

In the Venus' fly-trap, as in the East Indian pitcher-plant, only a portion of the leaf has been modified for insect capture,—a rounded terminal portion cut off from the leaf proper by a constriction, and hinged along its midrib so as to be capable of closing like a book. On this portion, the 'trap,' are three sorts of hairs essential to its operation

Fig. 10. THE SUN-DEW IN BLOSSOM, GROWING IN A HUMMOCK OF PEAT-MOSS.

—the first long and stout, fringing the edges of the two lobes, the second but six in number, three in the center of each lobe, and the third minute, innumerable ones covering the entire inner surface of each lobe.

If an insect alighting on a fly-trap leaf chances to touch any one

of the six slender hairs or to alight on the triangular area on either lobe which is bounded by the three hairs, the lobes of the trap immediately begin to close together. In perhaps as short a time as five seconds they have shut on the luckless insect, the stout marginal hairs have formed an interlocking fringe about the edge of the trap, preventing its escape, and the small hairs have begun to pour out digestive juices upon the hitherto dry surfaces of the lobes. Any touch, pres-

Fig. 11. The Venus Fly-trap.

sure or wound on the slender hairs or on the triangular areas will cause the lobes to close, whether the touch be that of an insect or that of an inanimate object. The other portions of the trap are so much less sensitive that it is necessary for them to be some time in contact with a nitrogenous substance in order to bring about closing of the trap. The contact of raindrops on any part of the leaf is without effect, and the other parts of the plant are entirely without sensibility. Still more effectually is the entrapped insect surrounded with the digestive juices than in the sun-dew, but the complete consumption of its soft parts may take many days. On reopening after a capture the trap will be torpid and unresponsive for some time, but if it has chanced to close

without getting a meal it will open within twenty-four hours and will be at once ready for a capture. The number of times that a trap will close and digest nitrogenous food is comparatively few; its delicate organization is soon worn out and ants may crawl over its face with impunity.

There is a wealth of interesting variety among other species and genera of the insectivorous plants, but the few described may well stand as examples of the whole number, for none depart very far from some one of these in the build and working of their pitfalls. While some of the traps are simple in structure and slow in action, and others are complicated and swift, yet there is a compensation in the fact that the more complicated devices are the most short lived.

The plants of insectivorous habit are not all members of a single family, and indeed are not all closely related—the group is a purely physiological one and owes its coherence to the fact that in all its members the meaning of the capture of insects is the same—the supplying of nitrogenous food. The very natural and pertinent question here arises: Why do these plants need such a remarkable means of getting nitrogenous food when other plants get on so well without this means? The insectivorous plants are obviously not able to subsist on insects alone, and—at least in the beginning of the habit—they were not different from other plants in their needs for nitrogenous food. So far as concerns the manufacture of starch and other non-nitrogenous foods the insectivorous plants are like all other green plants, deriving their carbon from the atmosphere, their hydrogen and oxygen from the water of the soil. It is in the elaboration of its more complex foods and the building up of new living substances in the process of growth, and particularly in the maturing of seed that a plant meets its need for nitrogen. In the ordinary plant this supply of nitrogen is derived from the nitrates which, together with several elements needed in small quantities, are brought up by the roots from the materials dissolved in the water of the soil.

Now, insectivorous plants in all parts of the world are found growing only in peat bogs, swamps, undrained pools and ditches—places in which it has been found that the water about their roots, from which they would be expected normally to draw their supply of nitrogen, is exceedingly poor in nitrates. Higher compounds of nitrogen exist in such places in plant and animal remains, but fail to be reduced to nitrates because of the absence of certain kinds of bacteria which carry on this work in all ordinary soils but are absent here because of the lack of drainage and consequent non-aeration of the water. It is this deficiency in available nitrogen, then, that is made up by a diet of insects, which are of course rich in nitrogenous substances.

How have such complex structures as those of pitcher-plant and

sun-dew had their origin in the course of the evolution of the plant world? Such a question will ever remain a mystery, and on its solution we shall be able merely to throw an occasional ray of light. Very many plants have their stems or flower-stalks beset with glandular hairs secreting sticky substances; an example in point, the clammy cuphea of our fields which sticks to the fingers tenaciously if we attempt to pluck its flowers. So far as known, the sticky secretions serve the plant in no way other than making it unpleasant browsing for herbivorous animals and ridding it of marauding ants, which become stuck to the glands and seldom escape. Might not such a condition have existed in the ancestors of the sun-dew? Might not the accidental catching of insects in this manner have formed the starting-point for the habit which is now so essential to the plant? Pitchered leaves are found too in many plants, and in many of them catch insects by pure accident, for example, the *Dischidia* of the East Indies. It is quite possible that further study of such cases may reveal new examples of the insectivorous habit, or may discover plants which have an imperfect or partial dependence on insect food, and any such discoveries would throw light on the development of the habit in its full-fledged possessors.

Marvelous as are the adaptations of the insectivorous plants, they have not been all these years upon the earth without certain crafty insects having learned not only to escape falling a prey to them, but to use them to their own ends. The pitchers of the Californian pitcher-plant are the home of a small moth which is provided with sharp spurs on its middle legs, which enable it to crawl easily over the slippery surfaces of the interior. So fearless has the moth become that it even lays its eggs in the interior of the pitcher, and here, protected from all the manifold dangers of the outside world, they hatch out in security. The young caterpillars spin a web over the slippery surfaces and the projecting hairs, making a safe path for themselves to the outside. There is a blow-fly which is able, too, to crawl over the slippery surfaces by aid of peculiar claws which give it a good sure footing. The grubs of this fly hatch out in the water of the pitcher and, far from yielding themselves up as food, they live here their brief term of larval life, and escape by boring a hole in the side of the pitcher.

In the South African hills grows a sort of bushy sun-dew, known locally as the 'fly-bush' (*Roridula*). This plant is a large consumer of insect food, owing to its size and the completeness with which twigs and leaves and even parts of the flower are covered with glandular hairs. Among its branches a spider has been found to spin its web. Not content with the supply of flies from its web, however, the spider goes forth upon the twigs of the fly-bush, and walking about in safety

among the glands, pulls off such insects as it desires and either devours them on the spot or returns with them to its web. Not less wonderful is the fly which pollinates the flowers of the fly-bush. It, too, is enabled, by possessing long legs, to walk in safety among the glandular hairs, and it takes pay for the service of having pollinated its flowers by puncturing the leaves and with its long proboscis sucking the juices of the plant.

So far as may be judged from rather limited observations the spider and the fly of the fly-bush are not found on any other plants. The spider has probably been attracted from other homes by the rich feeding ground, and, as for the fly, no one knows how complex may have been the history of its evolution. What more complicated relation between plant and animal can be imagined than this of the fly and fly-bush? A plant in need of nitrogenous food possesses effective traps for insects, from which this food is got. The plant is in need, too, of the services of insects for the pollination of its flowers. How can this plant, a death trap to insects, secure their service in pollination? Its large showy flowers attract many insects, but they find no honey to reward them for their visit, and if they linger about the plant their doom is sealed. The flower is not without honey, but the cells containing it are covered by a layer of ordinary cells, and when the long-legged fly makes its visits to the petals its proboscis is brought into use, the layer of cells is punctured, and the honey obtained. Insured against harm the fly may then visit other parts of the plant, and here it will use its proboscis again on leaves or stems to plunder the plant of its sap.

How much akin these phenomena are, you will say, to bribery, deceit and the taking of unfair advantage. True, there is no altruism among the lower forms of life; the benefit of self and of posterity is the supreme good of the animal and of the plant, and necessarily so by reason of the multitude of competitors and the keenness of the strife with them. Yet the great mass of plants live independently and, so to speak, honestly; overcoming obstacles and withstanding reverses, doing no more than energetic men in jostling their neighbors in the winning of a livelihood, and being no more than normal in providing that their own offspring should have a good start in the world rather than the offspring of their neighbors.

HEBREW, MAGYAR AND LEVANTINE IMMIGRATION.

By Dr. ALLAN McLAUGHLIN,
U. S. PUBLIC HEALTH AND MARINE HOSPITAL SERVICE.

Hebrew Immigration.

THE persecution of the Hebrew race finds no parallel in history. Other races have suffered at the hands of the conqueror, but these other persecutions are transient and intermittent compared with the persistent persecution to which the Jew has been subjected for centuries. One thousand years before Strongbow landed in Ireland, Titus destroyed Jerusalem, slaughtered thousands of its brave defenders and carried many thousands more as prisoners to fight the beasts in the arena or serve as slaves in the Roman galleys.

It may be said that persecution of this race has never since ceased. No century of the christian era passed without its record of persecution of the Jew. Adrian, Trajan and their successors kept up the work begun by Titus, and the first real respite from persecution was secured to the Jew by the conquests of that Semitic conqueror, Mahomet. But while the Jew was respected and his work in science and letters encouraged by the Saracens in Asia and Africa, he was being persecuted consistently by christians in Italy, Spain, France, Germany and England. This persecution continued throughout the period of the Crusades and down to the beginning of the nineteenth century.

Napoleon I. was one of the first sovereigns in Europe to cease discriminating against the Jew, and extend to him the rights of citizenship. Since that time other countries, notably England, have removed the ban from the Jew. In Poland the Jew was not persecuted to any extent previous to the partition of Poland, but with the beginning of Russian domination in Poland and Lithuania, one million Jews came under the iron rule of the Czar. Jews had existed in Russia from very early times, but most of the Russian Jews of to-day are descendants of the Jews who lived in Poland and Lithuania before those countries became a part of Russia. When one reads of the history of the Jewish race, with its story of persecution, cruelty and discrimination, a feeling of wonder and admiration must be felt for this remarkable people, which, in spite of almost universal oppression, exists to-day as the purest racial type in the world, and which furnishes the world with more than its share of great men in finance, art, music, science and literature.

That the Hebrews as a race have survived at all is a tribute to their splendid vitality. Not least wonderful is the fact that they have developed a common language in spite of their widely scattered distribution, among half a hundred alien peoples. This language, called Yiddish, is a corrupt German, modified by the addition of Polish and Hebrew words and suffixes. By means of this language expressed in Hebrew characters, and read from right to left, the Jewish people have preserved an extensive literature, mostly historical and religious in tone.

The persecutions endured by the Hebrew in the past were exceeded in severity by the comparatively recent anti-Semitic outbreaks in Russia and Roumania, and in the consideration of the Hebrew immigrant we are chiefly concerned with Russian, Roumanian or Galician Jews. German Jews formed a part of the great German exodus of the eighties, but to-day they, as well as the Hungarian Jews, are seldom seen among the immigrants.

The Jews moved eastward from western Germany and the Rhine valley under stress of persecution of the middle ages. They were welcomed by the kings of Bohemia and Poland and grew in numbers and prosperity in those countries until Bohemia came under the dominion of the House of Hapsburg, and Poland was divided between Russia, Prussia and Austria. Since the partition of Poland, the Jews have suffered, as well as the Catholics of Lithuania and Poland, from the religious enmity of the Russians. During the reign of Czar Alexander II., the stringency of oppressive anti-Semitic measures in Russia was relaxed, and the condition of the Jews in Russia was much improved. The assassination of the good Czar Alexander II., an event entirely unconnected with the Jews, was followed by terrible anti-Semitic outbreaks in southern Russia, and by the tyrannical enactments known as the May laws of 1882. These laws provided that the Jews, who hitherto were permitted to live anywhere within the Jewish pale, which comprised a territory of over 300,000 square miles, were now forced to prove that they possessed their right of residence previous to 1882, or, in default of such proof, to move into the towns. Many Jews, owing to the relaxation of the laws under Alexander II., had established themselves without the pale, and these now were forced back to add to the confusion and misery of the inhabitants of the towns. Within eighteen months of the enactment of the 'May Laws' the population of the little town of Tchernigov increased from 5,000 to 20,000 souls, and this terrible overcrowding was as marked in nearly all other towns within the Jewish pale. The economic pressure in the towns, the consequent hopeless competition for existence produced by these edicts, can be understood, and conditions grew worse as the population increased.

The first great exodus to England and America began soon after the enactment of the May Laws, and, owing to the reign of terror existing in the towns, resembled an indiscriminate flight. After a time the traffic became organized through the activity of steamship agents, and, the economic causes still existing, the stream of emigrants has since been almost constant. In addition to the oppressive enactments, an absurd story of ritual murder has been circulated among the ignorant Slavic peasantry for the purpose of inciting anti-Semitic feeling. Michael Davitt, the Irish patriot and writer, after a recent visit to Russia, thus sums up the situation in his book 'Within the Pale':

> The murderous competition for employment, the deadly rivalry for existence, the bad blood between opposing races, the poverty and social wretchedness which such a condition of things would create—apart from the operation of coercive laws—can readily be imagined by the American reader. But this is no overdrawn picture of the economic anarchy prevailing within the Russian pale of Jewish settlement.
>
> The towns are crowded with artisans and traders, and as these are out of all proportion to the producers and consumers of an agricultural country, they necessarily become more destitute and wretched as their numbers increase. They are too poor to emigrate. They are prohibited from migrating. They can not seek work on land. They are not permitted to engage in several occupations.

Mr. Davitt asserts that the Czar can accomplish much for the Jews in his domain by destroying the legend of the blood atonement. He avers:

> M. de Plehwe and the Czar can accomplish one good and blessed work, if so minded, without altering a single anti-Semitic Russian law. The Emperor can destroy in Russia the atrocious legend about the annual killing of christian children by Jews as an alleged part of the blood atonement in Hebrew paschal rites. In this humane and christian task he is entitled to the cooperation of the Emperor of Austria, the King of Roumania, and the heads of the other Balkan states, where this story of ritual murder is constantly circulated, and not infrequently as a part of political propaganda There ought to be a truly christian crusade waged against this infamous product of ancient, insensate, sectarian hate.

In Roumania the intolerant attitude of the government and a series of oppressive enactments against Jews constitute the chief cause of emigration. These measures of persecution employed in Roumania were in violation of the Berlin Treaty of 1878, which guaranteed religious liberty and equal rights to all. The Roumanian government maintains that the Jews are aliens, and to give them equal rights would mean that they would control the country in a few years.

Galicia under Austrian rule has no legislation against Jews in force, but a strong anti-Semitic sentiment exists, and no doubt this prejudice aggravates the economic problem which is the chief cause of emigration from Galicia.

Much is heard of assisted immigration, and no doubt the majority of Russian and Roumanian Jewish immigrants are assisted at some

point in transit, but it can be stated definitely that Jews in America neither individually nor collectively assist or encourage immigration to this country. They have sent representative men to Europe to confer with leading Jews of London, Berlin, Frankfort, Vienna, Paris and other centers in an effort to prevent wholesale emigration and to divert the stream from the United States. On the other hand, European Jews and Jewish societies, especially in England, have assisted thousands of destitute co-religionists and passed them on to America. Baron Maurice de Hirsch, the Rothschilds and other Jewish philanthropists have assisted the Jews to found colonies in Palestine and Argentina. In spite of these attempts to divert the stream from America, the bulk of the exiled European Hebrews land eventually in America. The American Hebrews realize that the chances for individual prosperity in the Hebrew immigrants depend upon their wide distribution. The more they congregate together, the greater the tendency to chronic poverty and pauperization. The success of the German Jews and Jews of other nationalities who came here years ago was due to their wide distribution, and competition with Americans in general, rather than the competition with each other for existence which is a necessary adjunct of life in the Ghetto. For these reasons American Jews, individually and collectively, are doing everything in their power to distribute their kindred over a wider area. In their work of caring for their poor they have encountered two obstacles which can be put down as the chief causes of the poverty of the Ghetto —one is the physique of the Hebrew immigrants and the other is their occupations. In physique they rank below all other immigrants, and few seem capable of hard physical labor. They seem to have no muscular development, and are prematurely old at an age when a German or Scandinavian is still in his prime. This poor physique is due to their living in the crowded quarters of cities and towns and to the occupations in which they have been engaged. These were conditions in Europe over which they had no control, as they were not only restricted as to residence, but were prevented by law from engaging in agricultural pursuits. Yet now when they are no longer subject to restrictive laws they cling tenaciously to the life in the slums, and their sweat-shop occupations.

Their occupation here is always some light one, requiring the least possible expenditure of physical labor. They are necessarily tailors, tinners, workers in fur and leather and other light occupations. They are physically incapable of any but the lightest kind of agricultural labor and have a distaste for that, as evidenced by the almost general failure of their attempts at rural colonization. One of the few successes recorded in the history of Jewish rural colonization was only made possible by the establishment of a clothing factory, to which

industry the erstwhile farmers took as naturally as a duck to water. From 65 per cent. to 70 per cent. of these immigrants of poor physique remain in New York City, to add to the congestion of the lower east side. Of the remaining 30 per cent. the majority go to Baltimore, Philadelphia, Chicago and other large cities, where they are rapidly building up Ghettos similar to that of New York.

The geographical distribution of the Hebrews landed in New York during 1903 is shown in the table given below.

State.	Number of Hebrews.	Ratio to Total Hebrews Landed.
New York	50,945	67 per cent.
Pennsylvania	8,206	11 "
Massachusetts	4,130	5 "
Illinois	3,170	4 "
New Jersey	2,004	3 "
Ohio	1,521	2 "
Maryland	1,074	1.5 "
Connecticut	1,020	1.5 "
All other states	4,133	5 "
Total	76,203	100 per cent.

Four fifths of the male adults are skilled in some light occupation, and this fact, coupled with their physical incapacity for hard labor, forces them into the sweat-shop. The addition each year of thousands of these sweat-shop workers to the lower east side of New York has produced a condition of affairs that beggars description.

Manager Frankel in 'The Twenty-seventh Annual Report of the United Hebrew Charities of New York,' October, 1901, says:

No matter how earnestly we labor to care for the Jewish poor, already in our city, our burdens are being constantly increased by the thousands who come from Europe every year and settle in our midst. It is worth noting in passing, that, comparatively speaking, few of these newly arrived immigrants come to us for assistance until after they have been in New York for a year or two. Either they have sufficient means of their own to bring them to America and to support them for a period after their arrival or they have been sent for by relatives, who are able to give them assistance for some time.

But the evil conditions of the houses and the deteriorating influences of the sweat shops of the great Ghetto soon work havoc among these people, and after an interval of two or three years they come to us in numbers for relief. . . . Furthermore, in line with our belief, that the ounce of prevention is worth a pound of cure, and that as law-abiding citizens of our country, we should not run against public sentiment nor pose as violators of the law, we have come to an understanding with the London Board of Guardians whereby the unwise shipment of Jewish immigrants, who are not adapted to conditions of life in this country, will be stopped. Hitherto we have had to bear the burden which should properly have been borne by our British co-religionists. They were perfectly willing to furnish free transportation to those persons who were unable to make a living in England, but who believed if they could only reach the shores of America (which means New York to all Jewish immigrants) their troubles would be at an end. . . .

What do these figures [here omitted] mean? The answer is easily given, and is but a repetition of the statements made to you in these annual reports for the past few years. They mean, if they mean anything, that a condition of chronic poverty is developing in the Jewish community of New York that is appalling in its immensity. Forty-five per cent. of our applicants, representing between 20,000 and 25,000 human beings, have been in the United States over five years; have been given the opportunities for economic and industrial improvement which this country affords, yet notwithstanding all this, have not managed to reach a position of economic independence. Two thousand five hundred and eighty-five of the new applicants, representing seven per cent. of the Jewish immigration to the United States during the year, found it necessary to apply at the office of the United Hebrew Charities within a short time after arrival. It must be remembered, furthermore, that the United Hebrew Charities does not represent the entire Jewish poverty and dependence that exists in New York City. Frequently our relief bureau is the place to which the applicant comes only after exhausting every other possible means of procuring assistance. When the numerous small relief societies, chevras, lodges, benefit societies, synagogues, individuals and others can no longer contribute, then and then only in many cases is the cooperation of the United Hebrew Charities sought.

If, besides the 50,000 people who applied at the United Hebrew Charities, we were to include in the dependent classes all who needed service of dispensaries, hospitals, asylums and institutions of all kinds or who were assisted by charitable effort other than that given by us, the statement can safely be made, that during the year from 75,000 to 100,000 members of the New York Jewish community are unable to supply themselves with the immediate necessaries of life.

The Hebrew has succeeded in America whenever he has separated himself from the Ghetto, and once away from all its influences Americanizes much more readily than is generally supposed. Other obstacles are in the way of transferring the Jews from the Ghetto to the country. The natural desire to be with their own people—to hear their own language, to be able to observe all their religious and social customs without fear of ridicule or interference, which the Jews possess in common with other alien races—make it difficult to get them away from the Ghetto. Then, too, the remuneration from agricultural pursuits is not enticing, and the opportunities for education and advancement to be found in the cities attract the Jew as well as the thousands of our native rural population, who flock to the great cities every year.

The hope for future betterment of conditions in the Jewish quarter of New York will lie in temporarily checking the Jewish immigration to this country, and in thus giving the Hebrew charitable organizations time to adjust conditions in the congested area. At present the good work performed in one year by finding places for poor Hebrews in other parts of the country is nullified the next year by the influx of thousands of new arrivals of the same character. If the stream of Hebrew immigration could be diverted for a time, those already here with the ample assistance of their charitable co-religionists might be distributed and made independent of charity. The realization of the dream of Zionism would tend to this result. Zion would hardly attract many Jews from

America, but it would receive the bulk of the Russian and Roumanian emigrants, and thus relieve the pressure here.

Two facts concerning the physique of the Hebrew race in general have been frequently noted. These are their longevity and their freedom from consumption. These facts seem rather inconsistent with the known poor physique of the Jewish immigrant. The first can be explained by their abstinence from hazardous occupations, their relative immunity from tenement house conditions, and the care which the Jews bestow on their sick. The freedom from consumption claimed for Jews in other parts of the world can not be said to obtain in New York. Consumption is very prevalent among them and is probably due to a combination of climatic influences and their manner of life in the Ghetto. Tenement house conditions alone could not explain the relative frequency of consumption, because they have been exposed to just such conditions for centuries.

The physical inferiority of the Jews is partially offset by their mental capability. Their intellects are sharpened by centuries of mental training. They possess in a remarkable degree the power of concentration of mind upon the object to be attained and a dogged pertinacity that spells victory for the student. They will deny themselves anything to obtain an education, and, when they have the opportunity, occupy a prominent place among students in every branch of study.

The Magyars.

The tiresome routine of inspection at Ellis Island produces varied effects upon immigrants, according to their temperament or race. Slavs drift through with blank faces and animal-like docility. The diminutive representatives of the Latin races appear frightened, but their faces are alert, eager, watchful. The Irishman treats the whole matter as a huge joke, and passes the inspectors with his cap on one side of his head and wearing a broad smile. The Magyar differs from all others, no halting hesitation in his gait, no evidence of terror or uncertainty, but he walks with military precision and confidence and something of a challenge in his bold defiant eyes. In short, he evidences the carriage of the trained soldier and the unconquerable spirit of a proud, warlike people.

About the close of the tenth century we find the Magyars established in what is now Hungary, under the leadership of Arpad. They undoubtedly came from east of the Carpathians at this time and came originally from the Finno Ugric cradle in western Siberia. They were probably akin to the 'Huns' who devastated Europe under Attila in the fifth century. Like the Huns they were absolute barbarians and carried war and pillage during the first century of their advent through the countries to the west and south. They were finally defeated by

Otho the Great of Germany and forced to accommodate themselves to a settled, peaceful existence. They adopted christianity and western political institutions and showed themselves as progressive in civilization as they had been skilful in war and pillage. The last of the line of Arpad, Andrew III., died childless in 1301, and the crown became elective. The first Hapsburg to be elected king of Hungary was Albert V. of Austria (1438), and the House of Hapsburg has since considered the kingdom of Hungary a part of its heritage. Owing to civil strife and rival claimants for the throne, the Turks obtained a foothold in the country about 1541, and their possessions were retained until finally driven out by Prince Eugene in 1718. The long stay of the Turks in Hungary was made possible by Magyar jealousy of the growth of Germanic influence. This feeling has never disappeared and was largely responsible for the brave defense of the young queen Maria Theresa by Magyars when her throne was threatened by Prussia, France, Bavaria and Saxony. After 1815 a great revival of national feeling was manifest among the Magyars. This movement was characterized by a demand for personal and constitutional liberty and a remarkable activity in literature. Many liberal reforms were achieved, but the suppression of the misguided revolt of 1848 set back the cause of national constitutional liberty twenty years. In 1867 the wise and good Franz Joseph saw the necessity of conciliating his Magyar subjects, accentuated by the humiliating defeat of Austria by the Prussians in 1866. The result was the dual monarchy as it exists to-day with a complete restoration of the constitutional liberties of the Magyar. Under the new order of things the Magyars have performed wonders in the establishment of commercial and industrial prosperity. Their progress in agriculture and manufactures, in railroad building and architecture, has been the marvel of Europe. And their economic progress and commercial expansion have earned for them the title of the Japanese of Europe.

From a country so prosperous and so greatly favored by nature as Hungary, we can scarcely expect to receive the best type of her subjects as immigrants. It is probable that the best type of Magyar has no inclination to leave his native land, and necessity compels but a very small number to emigrate. The Magyar immigrants are usually unskilled laborers and find employment chiefly in the mining states; 36 per cent. of their number landed being destined to Pennsylvania. Physically they are active and strong, and 90 per cent. can read and write. In fact, the Magyar seems an ideal immigrant but for one fault, his lack of permanency. Their intense national feeling and love for their native country make them, like the Englishman, slow to adopt American citizenship. They have a tendency to go back to Hungary and in flitting back and forth from Europe to America are

second only to those ‘prize birds of passage,’ the Italians. They are very industrious workers and rarely become public charges, so must be given credit for the amount of work they do, even if their permanency as citizens is open to question.

The distribution of Magyars landed in 1903 is shown by the following table:

State.	Number of Magyars.	Ratio to Total Magyars Landed.
Pennsylvania	9,701	36 per cent.
New York	5,291	19 "
Ohio	4,489	17 "
New Jersey	3,661	13 "
Connecticut	983	3.5 "
Illinois	760	3 "
Indiana	555	2 "
West Virginia	443	1.5 "
All other states	1,241	5 "
Total	27,124	100 per cent.

Levantine Races.

From the countries bordering on the eastern end of the Mediterranean Sea we receive several thousand immigrants each year, who are so far below all others in the matter of desirability that they are in a class by themselves. This scum of the Levant includes Syrians, Armenians, Greeks and Turks.

The Greeks are the best of this rather bad lot. Some few are producers and are engaged in textile industries, many more are peddlers and push-cart men. They establish Greek quarters in large cities and are probably under the control of padroni. Often when they are examined at Ellis Island, each member of a large party of Greeks will be in possession of the same amount of American money and all tell the same story, giving evidence of having been instructed and brought out in large parties by some one who probably controls their labor here.

The Syrians and Armenians are producers to a very limited extent in silk and cotton industries. The majority of Syrians and Armenians are engaged in trade, either as small shopkeepers or itinerant peddlers.

The activity of steamship agents in southeastern Europe and the establishment of a regular oriental steamship service from Marseilles to the Piræus, Beirut and Smyrna, have had much to do with the increase in Levantine immigration. Greek immigration particularly is stimulated by the enterprising Greek population of Marseilles, who reap handsome profit from the traffic, as all these oriental immigrants are landed at Marseilles and shipped from there overland to Havre, Rotterdam or other Atlantic ports.

The Syrians and Armenians ascribe as the cause of their expatriation the rapacity and misrule of the Sultan. Well-meaning American

missionaries have done much unwittingly to turn the tide of emigration from Asiatic Turkey to the United States. Young Syrians and Armenians educated here through the kindness of missionaries have advertised America, upon their return to Asia, as the land of promise, and thus increased our arrivals from Asia Minor and Syria. The majority of Syrian immigrants are orthodox Greek catholics, and very few Mohammedan Syrians come here. The Greek catholics or Maronite catholics will promptly espouse some form of protestantism in order to get their children into an institution. They are quite as ready to renounce the Greek religion for the Roman catholic for the same reason, to be rid of the responsibility of their young children. They always associate America in their minds with missionaries and charitable institutions. These traits have given the Syrian and Armenian a reputation for mendacity and lack of principle which can scarcely be said to be undeserved. The servile fawning humility and utter absence of spirit which these Syrians and Armenians exhibit are not attractive, and are but a pretense to cover the guile of the oriental. Bright young Syrians utilize religion to secure an education, then coolly repudiate all obligation to their missionary friends and engage in trade in the United States. The Syrian is averse to work of any kind, but he will never work at hard physical labor. He sends his wife and children out to peddle from door to door the oriental rugs, silks, laces and peddling truck. From peddling it is only a step to begging, and many of these peddlers combine the two vocations. The Syrian often goes into manufacturing small articles for this trade, using lofts in the Syrian quarter as work rooms, and employing men and women of their own race. They manufacture combs, brushes, hatpins, razor-strops, aprons, garters, suspenders, tooth-picks, crucifixes and other small articles for the peddling trade. The women earn from two to three dollars per week, and men make a little more, from four to six dollars per week. The Syrian women and girls also make the lace which they sell upon their peddling trips. The Syrian men and women peddlers make long trips from their headquarters, New York, and like true parasites follow in the wake of the rich to the seaside and summer resorts in the hot months, and to Florida or other parts of the South in the winter.

The Armenian immigrants, like the Syrians, are mostly traders, but a few are cigarette makers, and a small number are employed in the silk factories. Even the small percentage of these races employed as producers in the silk mills must be classed as unnecessary and competitive.

To the Greek, Syrian and Armenian quarters in New York, newly arrived immigrants go direct; and the congestion in these tenements is steadily increasing. The conditions which exist in the tenement of the Syrian or Greek quarters must be seen to be appreciated. No

words can describe adequately the overcrowding, the filth, the lack of air and sunlight, the ignorance of the common decencies of life and the miserable poverty of the tenement dwellers. The tenement headquarters of the Syrian peddler is crowded from the damp, miserable cellar to the garret with women and children, often a half dozen women, whose husbands are on the road peddling and whose children are in institutions, occupying one small room.

The physique of these races is very poor, and the percentage of loathsome or contagious diseases found among them is very high. During 1903, one Greek out of every thirty landed was sent back as likely to become a public charge. One Syrian out of every 28 was sent back for the same reason, and one Armenian out of every 58 was deemed incapable of making a living and sent back during the same period. In the matter of disease in 1903, one Syrian in every 100 and one Armenian in every 67 were sent back because of loathsome or dangerous contagious disease. One Greek in every 475 Greeks was sent back because of the same disability.

The mental processes of these people have an oriental subtlety. Centuries of subjection, where existence was only possible through intrigue, deceit and servility, have left their mark and, through force of habit, they lie most naturally and by preference, and only tell the truth when it will serve their purpose best. Their wits are sharpened by generations of commercial dealing, and their business acumen is marvelous. With all due admiration for the mental qualities and trading skill of these parasites from the near east, it can not be said that they are anything, in the vocations they follow, but detrimental and burdensome. These people, in addition, because of their miserable physique and tendency to communicable disease, are a distinct menace, in their crowded unsanitary quarters, to the health of the community. In their habits of life, their business methods and their inability to perform labor or become producers, they do not compare favorably even with the Chinese, and the most consoling feature of their coming has been that they form a comparatively small part of our total immigration.

The Greek immigration has shown the most marked increase, but Syrian immigration is also steadily growing, and without restriction, we may expect in the next few years, through the activity of the Mediterranean steamship agents, that many thousands of these human parasites will come here to reap the benefits of our civilization and increase instead of sharing our burdens.

MORE MEN IN PUBLIC SCHOOLS.

BY RICHARD L. SANDWICK.

AMONG the recent movements in education, none is more worthy of notice than the call for more men in public school work. The proportion of women teachers has grown steadily. Fifty years ago the men engaged in school work outnumbered the women; the civil war reversed this, and the gap has widened every succeeding year. There are fewer men teaching to-day than there were in 1860, but there are four times as many women. Women will probably continue to do a greater part of the teaching. It is generally recognized that women are better suited than men to instruct young children; and there is certainly a place for them both as teachers and students all the way up from kindergarten to college. Women have exerted a softening and humanizing influence that is accountable in part for the change from the rough school of fifty years ago, from which the teacher was not seldom pitched into the road by his bigger pupils, to the happy, orderly school-room of to-day. Women teachers have accepted a salary of scarcely half what men of like capacity would have accepted. They have thus been the means of extending the public school system to a point far beyond what tax-payers would have borne if equal intelligence had been secured from men. For these and other services in education women are to be congratulated.

And yet we can not help believing that any further increase in the relative number of women teachers would not be to the interests of education. Women outnumber the men in high schools already; and below the high school they reign supreme. Many large city schools of grammar grade employ no men teachers. A majority of boys and girls never come under the instruction of men. There is danger in this of a one-sided development: both sexes are being educated by the sex whose relation to the political and industrial systems is not usually that of either voters or wage-earners.

Less than one woman in five is engaged in earning a living. Of these comparatively few are under the necessity of so doing. They seldom have persons dependent upon them for support, and not often would suffer if thrown out of employment. Their earnings are usually additional to the support given them by others and are regarded as supplementary to the family budget. Even when engaged away from home they can usually count on a father's support in case work fails. Marriage relieves most women of the responsibility of self-support, and

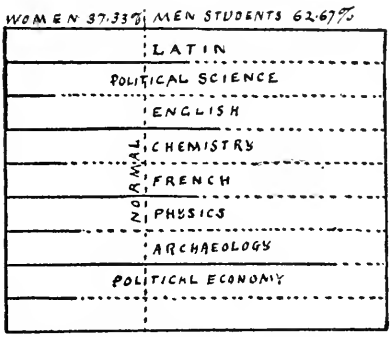
parents are willing to keep their daughters at home longer than their sons. The woman teacher has not been accustomed from early life to the thought that she must one day earn her living. She knows even after entering the school-room that her career as teacher is likely at any time to be cut short by marriage. Comparatively few women are wage-earners; the economic condition of the woman wage-earner is, moreover, quite different from that of the man; and the difference lies in the fact that the one is much less under the necessity of work than the other. It might naturally be inferred that the education of both sexes by that sex upon which the necessity of earning a living is rarely imposed would tend to keep economic considerations in the background. And it is true. Even in the higher grades economic independence is seldom a conscious aim; and the esthetic has a larger place than the useful. There ought to be more sympathy than there is for the boy with a yearning as he enters the age of adolescence to get out into the work-a-day world and earn a place for himself; a thing which the enrollment shows he is pretty likely to do if school does not prove that he will be the gainer by delay, or appeal to this side of his nature.

The presence of girls in the same classes with boys is not without significance here. It acts as a reinforcement of the same tendency away from the economic side which we have noted as a result of teachers exclusively women. A study of the tastes and preferences of women students in our universities, as indicated by the studies they elect, reveals the fact that they are not influenced to a great extent by economic forces. Women choose the purely cultural courses. A much larger proportion of them than of men study languages and literature; while very few take seriously to physics, chemistry, mathematics, political economy and political science.

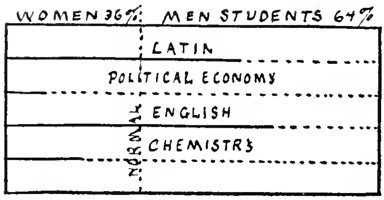
In the University of Chicago in 1900–01, there were 3,520 students registered in attendance, of whom 1,844 were men and 1,676 were women. The two sexes were thus fairly equal in point of numbers, the men out-numbering the women by 168. But in the language courses women greatly out-numbered the men. There were during the year 1,603 women studying English, and only 1,084 men; in French there were 468 women and 435 men; in Latin 621 to 430. In those courses which are more practical as being more closely associated with industry, the figures are reversed; here the men greatly out-number the women. In chemistry during the same year, there were 666 men enrolled and 120 women; in physics, 353 men and 90 women; in political economy, 354 men and 65 women. As showing that women are less interested in political and governmental matters, there were in political science only 68 women to 269 men.

These figures have been compared with statistics of other universities in the same subjects and they show a remarkable similarity. Where

the elective system is more freely allowed the choice of culture courses by women and of utility courses by men is still more marked. At the Leland Stanford Junior University in 1901–02, the number of students registered was 1,295, of whom 737 were men and 458 were women, the latter numbering only about three fifths as many as the men. Of the students electing English as a major subject, 156 were women and 58 were men; in Latin, 44 majors were women and 26 were men. On the other hand, in chemistry and economics the women made but a small showing; in the former there were 56 men to 13 women, and in the latter 62 men to 7 women. These figures will be more apparent in



Class Enrollment by Subjects, the University of Chicago.



Class Enrollment by Major Subjects, Leland Stanford Junior University.

the case of both universities cited, by reference to the graphs below. A large number of college women prepare themselves for teaching; it is probable that still fewer would be found in science courses if these were not demanded in the teaching profession.

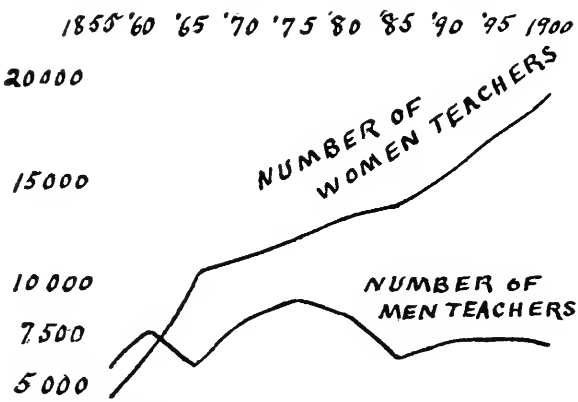
The great preponderance of girl students in our high schools coupled with the fact that more than half the teachers are women may account for the loss of ground which the sciences have recently met with in secondary schools. The period from 1890 to 1900 was one of rapid expansion in high school work; the requirements for graduation were greatly strengthened, in some cases the amount of required work being almost doubled. During this decade the number of students pursuing courses in history, algebra, English and the languages (Greek excepted) was greatly augmented; from 5 to 50 per cent. more of high

Year.	'89–'90.	'95–'96.	'99–'00.
Latin	34.69	46.18	50.61
Greek	3.05	3.11	2.85
French	5.84	6.99	7.78
German	10.51	12.00	14.33
Algebra	45.40	54.64	56.29
Physics	22.21	22.08	19.04
Chemistry	10.10	8.95	7.72
Geology		4.80	3.61
Physiology		31.94	27.42

school students being occupied with each of these subjects in 1900 than in 1890. But the percentage of students taking work in science has actually fallen off. The figures are taken from reports of the Commissioner of Education at Washington.

Greek is the only language that suffered a decline. The falling off in the number pursuing physics and chemistry is out of all harmony with modern industrial demands; students of these subjects in scientific and technical schools are being called to positions before they have graduated. Among those preparing to enter college, the sciences are losing ground, the classics gaining. In 1889–90, 51 per cent. of students preparing for college were preparing to enter the classical course, and 49 per cent. the scientific; in 1895–96, 52 per cent. were preparing for the classical, and 48 per cent. for the scientific; in 1899–00, 56 per cent. were preparing to enter the classical and 44 per cent. the scientific. The number of competent science teachers is now short of the demand, though language teachers are far in excess of it.

Coeducation has its share in forming sentiment and shaping instruction. The high school must suit its curriculum to the needs of its pupils; it has to give what is demanded. Since girls are in a de-



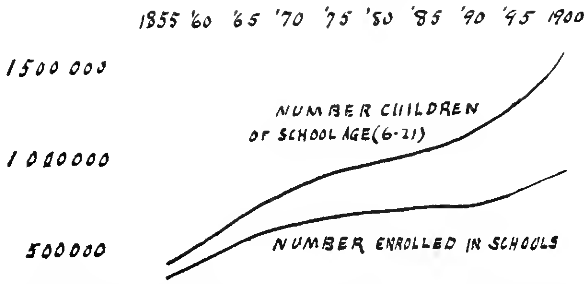
Growth in Number of Teachers Employed (1857-1900) in Typical State of Illinois.

cided majority, and the number of women teachers is in excess of the men, it is not strange that cultural courses receive the most attention.

Below the high school a still higher percentage of teachers are women. A circumstance that shows the effect of this on school work occurred to our notice a few years ago in a certain county of California. The attempt was made to introduce a little elementary physics into the ninth grade of grammar schools. The community was mainly rural; and it was thought that since most of the boys left school from that grade, it would be well to teach them the simple mechanical laws of pulley, lever, wheel and axle, screw, etc., to apply to their farm experience. It was a laudable design; but it was a failure. The teachers

were women, competent above the average, but they were not interested in that side of life, and they simply could not, except in rare instances, make a success in it. A flood of protest poured in from them to the county superintendent, and the subject was shortly discontinued. In view of the situation, we should not be surprised that almost everywhere in our public schools the esthetic has the preference over the practical—that poetry and literature receive more attention than arithmetic; painting and art than mechanical drawing; and music and the languages than physics, chemistry and industrial training.

Mr. Calvin M. Woodward, president of the St. Louis Board of Education, has made a study of the causes which impel pupils, and



GROWTH IN NUMBER OF CHILDREN OF SCHOOL AGE AND OF PUPILS ENROLLED, IN TYPICAL STATE OF ILLINOIS. The gap between these lines widens with increasing number of women teachers. Boys outnumber girls in primary grades but are outnumbered in upper grades.

especially boys, to drop out of school between the ages of 12 and 15. Circumstances are seldom such as to render it necessary for them to go to work for wages. Mr. Woodward says:

My deliberate conclusion, after a careful study of the matter, is that the prime causes for the abnormal withdrawals are: First, a lack of interest on the part of the pupils; and secondly, a lack on the part of parents of a just appreciation of the education now offered, and a dissatisfaction that we do not offer instruction and training of a more practical character.

The pupils become tired of the work they have on hand, and they see in the grades above them no sufficiently attractive features to invite them. They become discontented and neglectful; failure follows, they get behind, and then they stop.

As for the boys from 12 to 15 years old, their discontent is not unnatural. They are conscious of growing powers, passions and tastes which the school does not recognize. They find the restraints of the school room and grounds irksome. Their controlling interests are not in committing to memory the printed page; not even the arithmetic serves to reconcile them to school hours and school studies. They long to grasp things with their hands; they burn to test the strength of materials and the magnitude of forces; to match their cunning with the cunning of practical men and of nature.

The dissatisfaction of parents springs from several sources. The discontent of the boy or girl contributes to the feeling that the cost of books and the loss of a child's labor are too great price to pay for what the child is getting. As for going to the high school, it seems to the parent to be out of the question. The school is too far off, too costly in books, in dress and car fare, and not sufficiently practical in its course of study.

Mr. Woodward here recognizes the popular feeling that the schools are impractical. He has not noted the preponderance of women teachers as a contributary cause.

Women, as we have seen, are interested in the esthetic rather than the practical or the industrial side of life. In the boy's mind the grammar school with its corps of women teachers comes to associate education with the interests of women only. This I believe is one reason why so few take the step from grammar to high school. At this age boys begin to notice differences of sex. They are proud of their masculinity. The voice changes; they are conscious of superior strength, and they love to show their muscle. They cultivate the gruffer ways of men, and often learn to smoke and chew, not because they want to be vicious, but because men use tobacco and women do not, and they want to emphasize the fact that they are men. From fourteen to twenty they love football. It is a game that calls for masculine strength and masculine courage. So everything that is distinctly masculine is admired and imitated; everything womanish is despised. Few boys at this age are ready to admit that women are the equals of men. Even the mother's influence wanes. Her word is not final in everything. She is only a woman and can not understand all that men should do.

So it is in school. The woman teacher is at a disadvantage with high school boys. She must be of a decidedly strong personality to appeal to him. He sees intuitively that the tastes and preferences of women are different from those of men, and he is not at all ready to take a woman teacher's advice in choosing a course of action for himself.

We believe thoroughly in coeducation; but coeducation does not exist when both sexes are educated by one. The living teacher and the ideal his personality presents is more effective than anything else in holding students in school. The lady teacher can not present such an ideal to young people of the opposite sex. With all the growth in number of schools and teachers during the last half century, there are fewer men teaching to-day than there were in 1860. In spite of our boasted progress in education, there are fewer school children enrolled to-day in proportion to the number of school age than there were in 1860. If we would hold boys in school between the ages of 12 and 15, we must appeal to the more practical bent of a boy's mind, and the ideals of manhood which attract him. We must have more men teachers.

It was noticed above that women by their choice of studies in the university evidence very slight interest in political matters as compared with the interest exhibited by men. And yet they teach civics in a majority of schools. It will be interesting to endeavor to learn what the effect of this teaching is.

There is no doubt that we owe our extensive system of free public schools in great part to faith in the service of education as a training for citizenship. Webster was a firm believer in the efficacy of popular education to ensure the triumph of democratic principles. "We do not," said he, "expect all men to be philosophers and statesmen, but we confidently trust, and our expectation of the duration of our system of government rests upon that trust, that, by the diffusion of general knowledge and good and virtuous sentiments, the political fabric may be secure, as well against open violence and overthrow, as against the slow but sure undermining of licentiousness." It is on the faith that education has power to prepare for the duties and responsibilities of citizenship in a republic, that government has provided so generously for the public school system in taxation and grants of land.

Since Webster's time the rapid growth of urban communities has created a most extensive and intricate system of city government calling for detailed knowledge. To be merely a good man is not now sufficient to be a good citizen. Good citizenship requires more than 'the diffusion of general knowledge and good and virtuous sentiments,' if the tide of municipal corruption is to be turned back. Here the school fails. The civic function of our school system has no doubt suffered greatly from the fact that teachers are so little interested in current politics. Fear of 'mixing in politics' has held the teacher aloof from matters of this kind; and the teaching of civil government is often a perfunctory task. It can hardly be expected that those who are denied the right of suffrage should speak with authority on the duties of citizenship. Few teachers are acquainted with matters at issue in local elections; and few understand the real inner workings of party politics. Political patronage, the caucus, the convention and the primaries are little more than abstractions to most of them. It would be interesting to know how far the widespread apathy of educated people as to local politics could be remedied by more adequate instruction in the schools. General education and enlightenment no doubt has much virtue in effecting good government. The entrance of women into public school work, by extending the system to a point beyond what the public finance would have permitted if equal intelligence had been secured from men teachers, has been of inestimable value in promoting this general enlightenment. But so far as educating to an intelligent interest in political and economic matters of a technical character is concerned, our educational system has not yet done all that should be expected of it.

If there were a steady growth in public sentiment regarding extension of the franchise, such as induced the legislatures of half a dozen of our newer and less conservative states to grant women full suffrage, this weakness of civic education would tend to correct itself. But the

movement has been met by a counter movement among women themselves. An antisuffrage association has been active in Massachusetts for a number of years; in 1896 the New York State Association opposed to woman suffrage was formed, and in two years it had no less than twenty thousand members, a standing committee of a hundred, and branches in various cities. The Illinois Association, founded in 1897, issued a circular from which the following is quoted:

> A little reflection shows that the kind of intelligence which the law-makers should possess, the knowledge of practical things of the outside world, such as currency, banking, franchises granted to corporations, the general control of vast commercial and manufacturing interests, with other details of practical life not easily enumerated, are affairs which lie wholly within the affairs of men, and which it would be a sad waste of energy for women in general to become familiar with. Does it follow that women on the whole are inferior to men? By no means. In her own domain which includes the most vital, the most spiritual, the most progressive elements of life, woman is a man's superior as he is hers in outer and material things.

Through their clubs women have been active of late in municipal affairs. During the last decade they have aided materially in bringing about reforms in education, public charity and sanitation in several cities, notably in Chicago, Washington, Denver and Louisiana. It is to be hoped that they will occupy a still larger part of their leisure with problems of municipal reforms, and that a scientific discussion of such matters may get into the higher grades of schools.

The call for more men in public schools should be a call for more able men. So long as the marked superiority among women teachers continues, so long they should continue to be preferred. The difficulty lies in the fact that promotion and tenure of office are very uncertain, and salaries rarely sufficient to secure men of first-rate ability. The average salary of men teachers in the United States is higher than that of women, but it is still wretchedly low. It amounts to only $46.53 a month for 7 months and 6 days, or about $337 a year. According to Mayo Smith, the average wages of operatives, skilled and unskilled, were in 1890, for males, above 16, $498. Carnegie says in his 'Empire of Business,' "In one of the largest steel works last year the average wages per man, including all paid-by-the-day laborers, boys and mechanics, were $4 a day for 311 days." This would be $1,244 a year. Compare it with the $337 the male teacher gets, and judge of the average capacity our schools are likely to attract. The United States census for 1900 gives the mean annual wages of all laborers, including men, women and children, white and black, skilled and unskilled, as $437.96; one hundred dollars more than the average male teacher receives. If the salary, low as it is, were the only drawback the teacher contends with, he would be comparatively happy. He holds a political office, and though it is not usually under the system of political parties,

like all political offices not under civil service, it is exceedingly insecure. In the great cities positions are fairly permanent, but among the smaller towns every year brings its list of changes, and the teachers go bumping about from Podunkville to Daisy Hollow, often spending half a year's salary before they get a situation again, if in the annual shuffle they should succeed in getting any at all. If they do not procure a position the women teachers go home to their parents for a time, and then try it again next year; and the men, if they have any energy, go into other lines of business, leaving the inexperienced and unfit in the profession.

To sum up. Civic and economic considerations make it desirable that there should be a sufficient number of men teachers in the upper grammar and high school grades so that as many children as possible may come under the instruction of a man, for a time at least, before quitting school. Competent men can only be secured by an increase in salaries and a more secure tenure of office.

A SECOND CENTURY CRITICISM OF VIRGIL'S ETNA.

By Dr. CHARLES R. EASTMAN,

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CHIEF amongst natural phenomena to impose upon the imagination and challenge the understanding of classic authors was vulcanism in its direct and associate manifestations. Speculations as to the causes of earthquakes have at least as remote an antiquity as Thales and Pythagoras, of the sixth century B. C., and the relation between volcanic activity and proximity to the sea was clearly perceived in the time of Aristotle. Descriptions of Etna and Vesuvius have ever been a favorite theme for writers of both prose and poetry, the younger Seneca, in fact, complaining in one of his epistles that the topic had become trite and threadbare: "for this commonplace of poetry," as he calls it, "was fearlessly attempted again by Cornelius Severus even after it had been handled by Ovid, and more perfectly by Virgil."

Pindar's beautiful first Pythian ode, in honor of Hiero, has preserved for us not only the earliest, but at the same time one of the most graphic and altogether accurate accounts of Etna in eruption, so that it is scarcely dubitable that the poet was an eye-witness of the outburst whereof he speaks. The latter is in that case to be identified with the second eruption mentioned by Thucydides, the date of which is referred to the year 475 B. C. The odist's few masterly lines depict very clearly the principal features of an active volcano, and it is to be noted that some of them, such as the emission of smoke by day and flames by night, were recognized as typical characteristics by later observers and copyists, of whom Æschylus was the first.

Otherwise, however, was the case with Virgil, who, whether spectator or not of the disturbances which shook Etna shortly before the Christian era, drew more upon his imagination than upon observed facts for the portrayal given by him in the Æneid. Animated and suggestive as is the Latin singer's description of Etna, it lacks the verisimilitude of Pindar's, and this defect has given rise to the criticism of which we are about to speak.

The first to point out the lesser accuracy of Virgil's verse, as compared with Pindar's, was a philosopher of Hadrian's time, named Favorinus or Phavorinus, all of whose writings are lost. This criticism of the Virgilian Etna is preserved along with a host of interesting narrations in that curious scrap-book of Aulus Gellius, *Noctes Atticæ,*

being found in lib. xvii., cap. x., of that work.* Owing to its interest to modern readers, we venture to reproduce the entire passage, as follows:

I remember that the philosopher Favorinus, when in the heat of the year he had retired to his host's villa at Antium, and we had come from Rome to see him, discussed Pindar and Virgil somewhat in this way: "Virgil's friends and associates," said he, "in their memorials of his genius and character, say that he was wont to observe that he produced verses after the manner and fashion of a she-bear. For, as this beast produces its cub unformed and unfinished, and afterwards licks the product into shape and figure; so the results of his wits were at first rough-hewn and uncompleted, but afterwards, by rehandling and fashioning them, he gave them lineaments and countenance.

"Now," said he, "the facts prove that this quick-witted poet spoke with as much truth as frankness. For those things which he left polished and perfected—those on which he put the last touch of his censorship and his choice—rejoice in the full praise of poetical loveliness; but those of which he postponed the recension, and which could not be finished owing to the interposition of death, are by no means worthy of the name and judgment of this most elegant of poets. And so, when he was in the grasp of sickness, and felt the approach of death, he earnestly begged and prayed of his dearest friends that they would burn the Æneid, to which he had not yet sufficiently put the file.

"Now among those passages which seem to have been most in need of rehandling and correction, that on Mount Etna holds the chief place. For, while he wished to vie with the verses of the old poet Pindar on the nature and eruptions of this mountain, he wrought such conceits and such phrases that in this place he has out-Pindared Pindar himself, who is generally thought to indulge in too exuberant and luxuriant rhetoric. To put you yourselves" (he continued) "in the position of judges, I will repeat, to the best of my memory, Pindar's verses on Etna."

Now under sulph'r'ous Cuma's sea-bound coast,
And vast Sicilia, lies his shaggy breast
By snowy Aetna, nurse of endless frost,
The pillared prop of heaven, forever press'd;
Forth from whose nitrous caverns issuing rise
Pure liquid fountains of tempestuous fire,
And veil in ruddy mists the noon-day skies,
While, rapt in smoke, the eddying flames expire,
Or, gleaming thro' the night with hideous roar,
Far o'er the red'ning main huge rocky fragments pour.

"Now listen to Virgil's verses, which I would rather call *begun* than *made*."

Ample the port, and fenced to every blast;
But night and day grim Aetna thunders nigh
In frightful peals, and now and then doth belch
Black clouds of rolling smoke in pitchy whirls,

* The only complete translation of the 'Attic Nights' in English is that of W. Beloe, in three volumes, London, 1795. The passage on Etna, newly translated by Professor Saintsbury, is included in the *Loci Critici* of that author, pp. 74–75, his being the rendering we have made use of. It is necessary to add that the translation of Pindar given below is taken from West, that of Virgil from Thornhill (*Æneid*, iii., 570 sqq.).

With embers glowing white, and flings aloft
Great globes of fire, and licks the stars with flame;
Anon with large discharge out-hurls in air
The shattered entrails of the mountain's maw,
Disploded rocks, and jets of molten stone
Sluiced from its burning core, and brimming now,
O'er all its blazing sides infuriate boils.
'Tis said Encheladus' vast bulk is pressed,
All scorched and scarred, with thunderbolts intrenched,
This mighty mass beneath; and so o'erlaid,
The riven hill, in furnace mouths agape,
Forth spouts his fiery gaspings for the air;
And oft as shifts that weary, tortured side
Trinacria still from base to surface quakes
With inward throes, and shrouds the heaven in smoke.

"Now, in the first place," said he, "Pindar, paying more attention to truth, says what is the fact—what usually happens there and what is seen with the eyes—that Etna smokes by day and flames by night; but Virgil, while laboring for grand and sonorous words, confuses the seasons without any distinction. The Greek said clearly enough that fountains of fire belched from the bottom, and rivers of smoke flowed, and twisted yellow volumes of flame rolled to the shore of the sea, like fiery snakes. But Virgil, by choosing to interpret 'a burning stream of smoke' as 'a black cloud smoking with pitchy gusts and [glowing] ashes,' has heaped things together coarsely and without moderation, and has harshly and inaccurately translated what the other called 'fountains' into 'globes' of flame. Again, when he says that it 'licks the stars,' he has made an empty and idle exaggeration. Moreover, what he says about the black cloud, etc., is inexplicable, and almost incomprehensible. For things which glow are not usually black or smoking—unless he has very vulgarly and improperly used the word *candente* of ash merely hot, not fiery and shining. For *candens* is said of the brightness, not the heat.* But as for the stones and the rocks being belched and flung up, and the very same ones anon being 'liquefied,' and groaning, and being 'conglomerated in air'—all this is what Pindar never wrote, nor any man heard of, and is of all absurdities the most monstrous."

With respect to the anecdote related above that Virgil ordered his MS. to be burned, the same fact is mentioned by Servius in his introduction to the Æneid, and confirmed also by Pliny (lib. vii., cap. 30). Virgil died in 19 B. C., and the Æneid must have been published soon after. Just as Pindar's verse was imitated by Æschylus, so Virgil served as a model for the unknown author of 'Ætna,' a poetical description of more than 600 lines which abounds in scientific details. Although the authorship of this poem has been variously ascribed, the prevailing view of modern scholarship is that it is the work of Lucilius Junior, the philosophical friend and correspondent of the

* Strongly as Favorinus condemns Virgil's indulgence in poetic license, later usage would seem to sanction and uphold him in it. Dante's fondness for incongruous color associations, especially the more sombre shades, is proverbial, and even Milton did not disdain to put into the mouth of Moloch, when uttering his famous speech, the identical expression of 'black fire' (*Paradise Lost*, ii., 51-100).

younger Seneca, with whose writings it shows an intimate agreement. Notwithstanding it has been twice re-edited in English, and once in German, within recent years, almost no notice has been taken in geological literature of this remarkable production.* Sartorius, Baron of Waltershausen, who gives a list of ancient Etna eruptions,† refers to it casually as a 'schönes Gedicht.' Sudhaus, however, in his thesis on 'Ætna,' devotes considerable space to the scientific aspects of the poem, and traces a connection between the author's general theories of vulcanism and those of Posidonius.

An idea of the scientific value of 'Ætna' may be gathered from the following selections from the analysis of the poem as given by Professor Ellis in his critical recension of the text (Oxford, 1901).

ÆTNA.

(1–28) My song is of Aetna and its subterranean fires. The ancient subjects of poetry are exhausted and have become overtrite. Mine is a hardier effort, to explain the causes of Aetna's eruptions and of its burning lava floods.

(222–271) The highest pleasure of the human soul is to search into the causes of things. What is the origin of the universe, what is the nature of its framework? Will it pass into extinction, or go on forever? By what degree is the moon's orbit less than the sun's? What stars have a fixed circuit, what are the alternations of the zodiacal signs? Such lofty speculations as these should be our chief end and aim, as indeed they are our highest and most divine pleasure. Nor should we forget meanwhile the earth; for folly it were indeed to explore the sky and the stars, yet indolently neglect the great spectacle that lies before us and at our feet.

(187–217) If you ask what is the cause that produces the outbreaks of Aetna as we know them, I appeal to what we *see;* to *touch* we are not permitted, the force of the explosion making it dangerous to come near. Ignited sand is whirled up in a cloud, burning masses of rock are heaved skywards, a loud crash bursts from every part of the mountain, the ground is strewn in every direction with masses of sand and stone.

(447–507) Round the sides of Aetna you may see stones in a state of fuming heat, and rocks with the fire smouldering in their pores. When the volcano begins to prepare for an eruption there are premonitory signs, such as cracking of the ground, falling away of the soil, low murmurs from the depths of the mountain, flame. When these occur it is time to withdraw to the safety of some adjoining eminence. The eruption comes in a moment, masses of burning rock are heaved in the air, shoals of black sand are driven up to the stars. They fall into the most fantastic shapes. Some look like troops under

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*Gellius has fared better than the author of 'Ætna,' being quoted in full by seventeenth-century writers on Vesuvius, notably by Alzario della Croce, in his *Vesuvius ardens* (Rome, 1632).

† Sartorius ('Ætna,' Vol. I., p. 202) appears to be uncertain whether the combined statements of Virgil, Livy and Petronius refer to one or two violent eruptions about the middle of the first century B. C. It seems probable that only one is indicated, the date of which was either 44 or 49 B. C. Livy, as quoted by Servius, makes the eruption immediately precede the death of Cæsar in 44; Petronius, on the other hand, places it before the passage of the Rubicon in 49.

defeat,* some are still maintaining a sturdy resistance to the flames; in one part the fiery foe is putting forth its whole strength and seems to pant with the effort, elsewhere it is dying gradually down. The stones thrown out have a different look. Some have a dirty and rugged-seeming surface, like the scoria from smelted iron. Others that have fallen pyramidably upon each other burn away as if in actual furnace. Gradually the inner substance of the stone liquefies, assumes a more intense glow, and at last pours down the slopes of the mountain, sometimes advancing to a distance of twelve Roman miles. . . . But however far the lava-flood may be carried by its own impetus, crossing, for instance, the river Simaethus and joining its banks, once cold and stiff, it is almost immovable.

(602–fin.) Once upon a time the volcano kindled into flame and spread destruction over the surrounding country. So swift was its advance that the Catinaeans had hardly begun to know the fire was on its way when it had already reached their walls. Snatching up each what they thought most precious—money, gold vessels, armour, poems—they fled for life in vain, the flames surrounded and consumed them. Two only, Amphinomus and his brother, seeing their parents too infirm to escape, lifted them on their shoulders, and with this pious burden confronted the flames. O power of pity unsurpassable! The fire gave way on either side and would not assail them; they escaped with the burden which to them was more than all treasures, their father and mother. For this they are rewarded with eternal remembrance in poetry, and a special mansion in Elysium.†

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* One may compare H. A. J. Munro's felicitous explanation of this passage in his 'Ætna, Revised, Emended and Explained,' p. 35, (Cambridge, 1867).

† The names of the little village Pampiu, near Catania—supposed to be a corruption of *Campo pio*—and one of Etna's lava-streams, called *Fratelli pii*, commemorate this ancient legend even at the present day.

THE EVOLUTION OF THE HUMAN HAND.

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THE succession of organic modifications which resulted in the formation of the human hand is part of the general process of evolution by which in the animal series the means of progression and of the taking of food were shaped by the environmental conditions under which life was carried on. Antecedent to the appearance of vertebrate limbs a series of manifold devices had originated by which the body could be transported from place to place and appropriate foodstuffs seized and carried to the mouth. These consisted of more or less permanent extensions of the body substances, naked or clothed in protective shields of denser material. In some types the limbs were created in the act of extension itself and were retracted by absorption and disappearance into the general body mass; in some they were formed of erectile tissues which could be protracted or withdrawn as occasion demanded; in some the whole body was thus contractile, and alternately elongated and shortened as the animal progressed; in some the organs of locomotion consisted of definitely formed limbs, which, while subject to loss by violence or even sudden shock, might be repeatedly and perfectly regenerated in the course of the individual life. In the forms to which they are molded and the mechanical principles upon which they depend, these organs of movement present the utmost variety, including ameboid extensions, flagellate cilia, pulsating bells, contractile stalks and bodies, suckered tentacles, swimming fins and tails, wings and articulated legs. They appear as a great series of adaptive levels through which the evolution of this particular mechanism passed toward more highly integrated and developed types.

The functions of life which call into service the bodily limbs are chiefly two—locomotion, an activity which has arisen in connection with the search for food and flight from enemies; and prehension, which is concerned primarily with the grasping and tearing of food, but secondarily also with processes assistive of locomotion and other biological functions, such as sexual congress, the care of the body, burrowing and climbing. Of these two functions, if we regard the vertebrate class only, the former is the more primitive. Upon the office of locomotion the prehensive and manipulative activities of the limb have been superposed as subsequent and more specialized adaptations. In vertebrates of less modified types the food is seized and manipulated by the mouth parts directly. Fish, reptiles and birds

feed in this way. In these as well as in mammalian forms which present relatively slight limb specialization, the mouth parts have in many cases undergone modifications which render them effective instruments for grasping, rending, digging, picking and the like. Such adaptations are shown in the snouts of the mullet and pig; the beaks of the paddle-fish, the duck-billed otter, the humming-bird and the secretary; the tusks of the boar, the horn of the rhinoceros, the proboscis of the tapir, the tongue of the chameleon and the trunk of the elephant. In all these cases the specialization of the limbs which accompanied such modifications of the mouth parts consists in an adaptation of the function of locomotion in connection with the particular conditions under which the life of the species is carried on; in consequence of which their general features have diverged very widely from those of manipulative organs.

The earliest form of locomotion which vertebrate limbs fulfilled was propulsion through the water. The problem to be solved did not include the support of the body, which was buoyed up by the dense medium in which the animal moved. The same dense medium afforded a sufficient resistance to allow of a relatively slow and weak movement on the part of the locomotive organs. The earliest vertebrate limbs, or the body extensions which foreshadowed them in times still earlier, needed neither the strength and rigidity of the terrestrial leg nor the expanse and velocity of stroke of the aerial wing.

If we conceive the progenitor of the limbed vertebrate to have progressed by means of an undulatory motion of the whole body, brought about by a peristaltic wave of contraction passing from front to rear of the animal, it is not difficult to infer the advantages which would accrue to those individuals in which a modification appeared in the form of flexible extension parallel to the longitudinal axis of the body, by the independent undulations of which progression became possible. The economy resulting from reduction of movement in the whole body mass would be accompanied by a decrease in the likelihood of attracting notice, a greater control of movements in taking food, and a more exact process of perception in adjusting the body to surrounding changes.

Though the series of limb forms is obscure in its earlier parts, the whole group is generally supposed to have its prototype in the lateral fold of the primitive fishes, in which locomotion took place through a wave-like movement passing backward along the length of the web. Out of this primitive lateral fold the various fin-formed limbs which characterize the aquatic progenitors of the land vertebrates arose by a series of modifications in which the following stages may be noted: In the undifferentiated swimming folds first developed a system of parallel rods extending from the body surface to the margin of the web, which probably both served the purpose of increasing the resistance

of the locomotive organ and was accompanied by muscular and nervous developments which allowed greater definition and force in the reactions produced. Among these rods certain members outgrew the rest, a development which from mechanical causes alone would tend to survive in a bilateral form. The number of such points of origin of increased growth in the rods was finally reduced to two on each side of the body, after a series of forms which we may conceive to have presented a diminishing series of rods, as the lamprey and shark present numbers of gill arches intermediate between those of the lancelet and the perch. With the definition of these fore and hind pairs of axial spines a concomitant modification of the adjacent members of the system of parallel rods took place, in consequence of which, first, a differentiation in size arose among them, those in proximity to the axial spine increasing, those remote from it decreasing in length; secondly, changes in the points of their attachment to the body occurred, the system of secondary rods moving from the median regions in either direction toward the axial spines; and finally, these accessory rods arranged themselves in a radial relation to the central rib, thus giving anterior and posterior fan-like extensions connected by the remnants of the degenerating fold and rods in the intermediate body regions.

Further differentiation of the axial and neighboring spines, in which the latter were progressively affiliated upon the former and there appeared a definite point of articulation of the whole system with the body mass, gave rise to the bipinnate fin, a roughly symmetrical organ in which the main spine occupies a central position and is flanked by a group of supplementary rods on either side. From this form structural modification proceeded, first, by the reduction and disappearance of the accessory spines on one side of the main axis, giving the unilateral fin; and secondly, through a similar degeneration of those on the remaining side, by which the limb was reduced to a prong-like form represented in the lepidosiren. The limbs at this stage of development were in a condition which in general was more adapted to progression upon land than through the water, since the expansion upon which their propulsive action depended had ceased to be an element of importance, and all that was needed for terrestrial locomotion of a crude sort was a condition of sufficient rigidity in the limbs to allow of their use in dragging or pushing the body along, as the turtle does, but not necessarily of supporting its full weight as do the common quadrupeds. Before this final stage was reached, however, the animal had begun to practise land travel, using fins which were in the bipinnate condition as terrestrial limbs, as is the case with the Australian salmon, ceratodus.

From this primitive terrestrial vetebrate limb, through a series of cleavages of, or buddings from, its extremity, giving successively

two-, three- and four-toed forms, arose finally the five-toed generalized type of mammalian limb. The subsequent modifications of this organ, if we omit the divergent series of adaptations which gave rise to the pterosaurians and finally to the birds, present forms of specialization connected with the following modes of progression, namely, swimming, running, leaping and climbing. The first, exhibited in different degrees by the whale and the dolphin, we may pass by, both because it follows a process of adaptation unlike that of the group of animals to which man belongs, and because the change may be regarded as degenerative, inasmuch as the animal returns to a medium which makes less demand upon the structural resistance of the organism than did that which was relinquished. Adaptation to running finds its extreme form in the hoofed animals, in which the body is poised upon the extremity of the limbs, thereby conserving their full length for the purpose of rapid movement by employing the utmost length of stride; and in which the number of functioning toes is progressively reduced until, as in the horse, only a single massive and horn-shod central digit forms the body of the so-called foot. In adaptation to leaping, which is presented both by animals which have passed through an arboreal stage, as the kangaroo, and by others which have always been terrestrial, like the hare and jerboa, the structural modifications consist primarily in an increase in the size of and strength of the posterior limbs, with a concomitant degeneration of the fore limbs as they are less and less called upon to share in the function of supporting the body. Along with this primary modification goes a greater or less degree of specialization in the extremities of the limb, by which, as in the case of the running animals, one or more of these take upon themselves the chief support of the body and the rest suffer functional atrophy. In the jerboa, for example, one toe only is thus degenerate, while in the kangaroo three are rudimentary.

It is with the modification of the five-toed limb for the purpose of climbing that we are here especially concerned, since it is in the arboreal group of animals only that the specialization of the fore limb in the form of a hand appears, and since it is to the adaptations fostered by this form of existence that man owes the early development of his own dextrous and accomplished manipulative organ. This modification consists, first, in the modeling of the extremities of the limbs to a form which made the act of grasping possible; secondly, in the separation of the whole system of limb terminations into two opposable groups, by which primarily a more perfect grasp was secured, and later the refined manipulation of objects was made possible; and finally, in the differentiation of hind and fore limbs, by which the former were made to provide secure and rapid locomotion and the latter were left free for specialization controlled by the sole condition of prehension and manipulation.

The first of these functions appears to be essentially connected with the habit of walking on the sole of the foot—plantigrade locomotion —and not on the knuckles or toes—digitigrade locomotion. Another method of climbing exists which is common to the rodents and the cats. In these animals the act of climbing depends upon the development of claws sufficiently long, strong and sharp to be attached like hooks to the roughened surfaces upon which the animal climbs and thus to support the body. In such forms the modification is of a superficial feature of the body structure and is probably a secondary function, the claws having been developed in connection with habits of seizing prey rather than of climbing. There is here no essential modification in the anatomical relations of the various parts of the limb, and it is inconceivable that any such subsequent development should be connected with this form of climbing organ as is presented in the limbs of the anthropoid apes and man.

In the plantigrade animal, on the other hand, the disposition of the limb is such that when the weight of the body is thrown upon it the toes tend to be thrust apart even when the foot is resting on a flat surface, and to be forced into a concave shape when pressed upon a rounded object. It is probable that a fair degree of development in the joints of the limbs had taken place in both flexion and separation before they were used for the purpose of climbing. But flexibility and separability of the digits form only the intial step in the process by which adaptation to an arboreal life was perfected. The second—and beyond all other changes important—modification consisted in the structural opposition of one digit to the remaining group. This differentiation occurs also in the lizards, *e. g.*, the chameleon, and in the birds, under similar conditions of climbing and perching; but in connection with such specialization of the limbs in other regards and such modification of the body system as a whole that important service in the evolution of intelligence was precluded.

In the production of opposition changes took place in the hind limbs first and most generally, since all species in which the thumb is opposed possess opposable great toes also—except in the single case of man—while many species occur in which opposition is presented by the hind limbs alone. In this adaptation of the foot to climbing three structural changes were effected—the parts of the limb became more flexible, the joints more widely separable, and the great toe, as has been said, opposed to the group formed by the remaining digits. All these are important features in rendering the limb a more efficient tool.

For the development of those peculiar functions which characterize the human hand, however, a further change in the use of the fore limb was necessary, by which it was relieved from participation in the support of the body and in primary locomotion. This relief must

have taken place by a process which involved simultaneous changes in both fore and hind limbs. The support of the body, hitherto laid upon all four limbs, could not have been taken over at once in its final adequacy and security by the legs alone, unless we conceive of a spontaneous variation of improbably large extent. The animal at first raised itself hesitatingly upon its hind limbs, supporting its weight in part by the grasp of the hands upon higher portions of the trunk and branches, thus distributing the function as heretofore among the whole set of limbs, but in such a way that the fore limbs were adapted to their new specific use while performing their old generic function. The body, in this stage of development, was sustained in part by support from beneath and in part by suspension from above. Either of these factors may be conceived as appropriating a chief place in the locomotive function; and in different animal species these divergent directions of development are both presented, progression by swinging from limb to limb in the long-armed apes, and by the sole use of the legs in man.

It is probable that the progenitor of man, together with the whole group of anthropoid apes to which he belongs, maintained the quadrupedal position longer than those types which, like the Cebidæ, *e. g.*, the tee-tees and Capuchin monkeys, present no opposition in the members of the fore limbs. If we conceive the semi-upright position to have been assumed at a time anterior to the development of opposition in the hind limb, say at the beginnings of arboreal existence, so that from the outset each pair of limbs was modified under different conditions of function, it will be found difficult to imagine the causes which under these unlike circumstances brought about a similar modification in each set of limbs. If, on the other hand, both fore and hind limbs were used to support the animal in a quadrupedal position upon the branch beneath it during the early period of arboreal life, it will be as difficult to imagine a reason why both sets of limbs should not present the same type of adaptation. The condition which predisposes to conservation of the phenomenon of opposition is support, not suspension; it is peculiarly a modification of the foot. All that is involved in successful adaptation to the function of suspension is the existence of sufficient elongation in the digits, flexibility in the joints and strength in the muscles—the development of a strong and supple member, but not necessarily one possessing an opposable thumb. Even a single series of joints may form an efficient instrument of suspension, as in the case of the prehensile tail of the monkey tribe. For support upon the rounded branch beneath, on the other hand, some sort of forking is almost the only modification which could give security, and in the man-like ape this has taken the form of an opposition between a single member and the rest of the group.

We may therefore conceive that the progenitors of the Capuchins

and other parallel fingered species soon after their adoption of the arboreal habit—or at least before the appearance of any important modification of the earlier structural relations of their limbs—took to a form of locomotion in which the body was partly supported from beneath by the hind limbs and partly steadied or suspended from above by the grasp of the fore limbs; so that the peculiar modification which the arboreal form of life contributed to the animal type was incorporated in the hind limbs alone. The anthropoid apes, on the contrary, which show this specialization in fore as well as hind limbs, we shall conceive to have persisted in the quadrupedal habit during a period the continuance of which was sufficiently protracted to allow of the appearance of similar modifications in all four limbs. Only subsequent to this process of adaptation should we imagine the progenitor of man to have arisen from the quadrupedal position and to have used the fore limbs for the secondary support of the body by grasping the upper branches.

In this new function the limb specialized by opposition had probably little advantage over the more primitive hand of the monkey, in so far as suspensional support was concerned. In respect to those other uses upon which the subsequent development of man in all kinds of mechanical skill depends, this new structural variation was of the highest significance. The monkey tribe gave up the habit of walking on all-fours too early and is suffering from the consequences to the present day.

This stage of development, however, represents a condition in which the factors of further evolution are confused and the various parts of the organism imperfectly adapted to the functions they are hereafter to perform. Hands and feet conform to the same architectural type. Both share in the unitary process of locomotion; the hands are capable of supporting the fore part of the body in moving, the feet are still prehensile organs. There is no exclusive functional specialization by which fore and hind limbs may be set off from each other. This subdivision of labor must come about through a development of the lower limbs by which they become capable of the sole support of the body at rest and in progress. In other words, the hands can not be released from their office of steadying and supporting the body until sufficient skeletal changes and muscular growth have taken place in the lower limbs to enable them to carry on the function of locomotion alone. The freeing of the hand for exclusively manipulative purposes thus depends upon the replacement of the semi-erect posture by a fully erect one, in which process the calf develops, the joints are straightened and the whole limb rotates upon its point of attachment to the body until the main axes of the two are parallel and each is vertical in position.

These changes could hardly have taken place during the continuance

of an arboreal habit of life. The means of support afforded by the branches is too precarious, the form of locomotion which practical conditions impose upon the animal too restricted and interrupted to make the development of such a limb as the human leg possible. The need of supplementary support to which an unstable balance must give rise and the facility with which the arms can come to the aid of the legs as the animal makes its way from tree to tree are likewise factors which retard the development of efficient bipedal locomotion. The freeing of the hands may therefore be regarded as a concomitant of the return of man's progenitor to a terrestrial habitat, in which free, large and continuous movements of locomotion were both possible and necessary. Only on the wide, open spaces of the ground can we conceive the ape-man to have become a swift and sustained runner, holding the body upright and the arms free.

At the same time with the changes in the leg already described the habit of traveling over the level surface of the ground would tend to produce a closer knitting of the ligaments of the foot and a greater compactness and rigidity in its general structure. The opposition of the great toe, no longer necessary to preserve the animal's equilibrium—since this is sufficiently secured in a lateral direction by the relation of the two legs—becomes a distinct impediment to land travel, owing to its interference with the movements of the fellow limb and its liability to injury by striking upon the objects among which the animal walks. With the further development of the foot, however, whether degenerative or other, we have not here to do.

As regards the special causes which led to the adoption of a terrestrial habitat in preference to the earlier arboreal life, it is probable that the change was intimately related to the development of the opposable thumb. The platyrrhine monkeys have the same type of foot as that possessed by the man-ape and do not progress predominately by swinging as do the long-armed apes. Anatomically, therefore, they differ from the progenitor of man chiefly in the fact that, unlike him, they have retained the parallel-fingered hand. In this differential feature resides their disability. The monkey form of hand is adequate for seizing and clinging to branches, but deficient in adaptability to all other mechanical purposes. For grasping and pulling, for digging and tearing, for handling stones and sticks the human hand with its opposable thumb is incomparably superior. Among the uses for which, in virtue of these capacities, it is especially fitted are the employment of weapons, the construction of means of defense from attacks by carnivorous beasts and later the use of tools.

The relinquishment of an arboreal habit involved the giving up of an important refuge and the assumption of a mode of life assailed by many new and grave dangers. The tree is a place of safety; it affords a secure retreat from some enemies and concealment from many others.

A life amid its branches is compatible with a condition of weakness or defenselessness which would be fatal to the species under the circumstances of a ground habitat. To descend from the trees and venture that mode of life implies one of three possible resources: the animal must either be fleet of foot enough to distance his pursuers, or he must possess weapons of defense sufficient to repel attack successfully, or, finally, he must supply deficiencies in these regards through a cunning which enables him to escape his enemies by artifice. The apes are not swift of foot as compared with beasts of prey. They are poorly provided with natural weapons or means of defense. They have neither tusks nor claws, neither hoofs nor horns, neither great mass and strength nor impenetrable hides. If they are to take the aggressive or even to repel attack successfully it must be by the invention of artificial weapons whereby their deficiencies are made good; but as recourse to such instruments is a purely mental resort to obviate actual physical difficulties, it may be said that the ape-man met his difficulties in only one way, namely by cunning—escaping his enemy by retreat to strongholds of his own devising; meeting him, when battle was unavoidable, not with bare hands but with weapons, and taking his prey by traps and snares. But the schemes of his cunning brain could become practicable only as the result of a distinct mechanical constructiveness. Stones must be gathered and dropped or thrown with accuracy; clubs must be selected and wielded; traps must be put together after they have been devised. In all this the manipulative hand is essentially linked with the resourceful mind. With any other known type of limb the problem would have been insoluble. The specialization of the hand, therefore, with its opposable thumb and its wonderful adaptability to mechanical uses we may conclude to have been the single indispensible condition, so far as regards gross anatomical features, which determined the widely divergent subsequent fortunes of the monkey tribe and man-ape respectively.

For the principle of separation between this type and the rest of the anthropoid apes we must look to the different directions of development taken by the central nervous system in the two cases. Henceforth no important structural changes are to occur in the general features of the hand. Development is to take place chiefly through an increase in the facility and precision with which a variety of relatively simple movements are made, and the substitution, in ever increasing grades of complexity, of mechanical instruments for the use of the hand itself as a manipulative and constructive agent.

THE COMING INTERNATIONAL CONGRESS OF ARTS AND SCIENCE AT ST. LOUIS, SEPTEMBER 19–24.

By Professor SIMON NEWCOMB, U. S. N. (retired),

president of the congress.

AMONG the numerous attractions of the Universal Exposition at St. Louis, there is one which appeals with special force to all interested in the progress of learning. The assembling of congresses on various subjects has, especially in recent years, been so prominent a feature of great expositions of industry that such gatherings have recently tended to lose in interest. But the directors of the St. Louis World's Fair decided, at an early stage in their preparations, to make special efforts for bringing together a congress which should be more comprehensive in its scope, of wider interest in its discussions, and of more permanent value as a memorial of the exposition, than the usual conventions of this class. After holding several consultations with eminent scholars it was decided that the field of the congress should be as wide as that of science itself. The first question to arise in considering such a scheme would be how it was possible with the present multiplication of specialties in science to arrange a congress whose discussions should embrace a field as wide as that of knowledge.

It must be admitted that if the principal aim were to read and present scientific papers and researches nothing could result but the addition of a few more volumes to the almost unmanageable collection of published scientific literature. Farther consultations with educators and others led the directors to adopt a new plan for reaching the desired result, which was suggested and worked out in detail by Professor Münsterberg. Its idea was to supplement all the specialties by a discussion of the principles of the more important groups of sciences, and of the methods by which the sciences should be brought together, unified, and made mutually helpful.

That some effort of this kind is desirable must be evident to any one who contemplates the almost alarming increase of specialties in scientific research, coupled as it necessarily is with lack of knowledge on the part of any one investigator of the work being done by his fellows. We all know that new fields of research are continually being opened, and that the older fields are continually being extended into minuter specialties. New societies with their proceedings, and new journals are continually being established. Moreover the volume of papers published in any one established journal frequently goes on

increasing in a geometric ratio. To take a single instance: the *Astronomische Nachrichten*, established about 1825, now the oldest and most reputable astronomical journal of the world, began by supplying practically all the needs of astronomers for a medium of communication, by issuing perhaps one volume in a year. With every decade the number of volumes went on increasing until, in recent years, three or four volumes have been issued annually, and the one hundred and seventieth volume is soon to appear. But this is not all. Even with this continually increasing number, the publication has fallen short of the requirements of astronomical investigators, so that fresh media of communication have from time to time been opened. New scientific societies including astronomy, and new astronomical societies, are from time to time founded. *The American Astronomical Journal* founded by Dr. Gould in 1849, and revived in 1885, takes the place of the *Astronomische Nachrichten* in this country. The *Monthly Notices* of the Royal Astronomical Society have continually grown until the annual volume has become of alarming thickness. New astronomical societies add to the mass, and as if these were not sufficient, several great observatories have commenced series of their own. The result is that an astronomer can hardly know more than a small fraction of what is being done in his own field, and, if an attempt were made to subdivide this science into its minutest specialties, one would hardly know where to stop.

What is true of astronomy is true not only of all the older sciences, but of the new ones, which are from time to time being opened up, and of the various specialties into which every branch of science is divided. Dictionaries can not keep pace with the new -ologies, -ographies and -onomies,—and he is a scholar indeed who, on hearing the name of any science, could on the moment accurately define its field. Depressing indeed would be the prospect if scientific investigators could look forward only to an unending increase of this process of subdivision. When the number of serials becomes so great that a mere catalogue of them makes a book, as is now the case, and when the volumes of a serial mount up into the thousands, as they must before many generations pass, who shall be able to know what is contained in them? Most happily, we can see the possibility of an opposite process—the addition of integration to the indefinite differentiation with which we are so familiar. As we go deeper into all the laws of nature, we are led nearer and nearer to the belief that the fundamental principles on which her operations are carried on may be few in number, and that what seems to us a great diversity of laws may consist in the action of one and the same law under a variety of different conditions. It is true that the process of reducing all natural operations, even those of inanimate nature, to their first principles, is

a very slow one. We may well despair of ever reducing the phenomena of nature to such simple laws as that of gravitation. It may be that our hope of doing anything of the kind has received a great set-back by the iconoclastic way in which the discovery of radio-activity has shaken to its foundations what, ten years ago, were supposed to be fundamental principles at play in the material world.

But we still find the process of integration to be going on as our knowledge advances. The discovery of principles more or less general which, being mastered, will enable a single mind to grasp a continually widening field of research is constantly going forward. It is true that we are not to expect the revival of the medieval professor of all science; but we may look for a class of widely educated men who, if not masters of the details of any one science, will yet have at command so comprehensive a grasp of great principles as to be able to form an intelligent judgment on those questions of science and learning which are of the widest human interest, and which most influence the progress of the world. It is not necessary to burden the memory with details of the forms and habits of every species of animal or vegetable in order to form an intelligent idea of the general laws of life and of the conditions of its propagation. The intelligent reader of history may condense its lessons into small space, even though he fails to remember details of dynasties, battles or treaties.

This process is facilitated by the natural tendency of every science, when pursued by the best methods, to become more precise in the expression of its laws, and thus to bring mathematical conceptions to the aid of its investigators. When we have not only assigned a name to an object of study, but have made measurement of its size, or of the intensity of any ascertained properties it exhibits, we have taken a great step toward giving precision to our results, and making them comprehensible to a wider body of investigators.

With these preliminary considerations we see what interest attaches to the enterprise of bringing all the sciences together for a week's discussion of their problems and relations. That this is no easy task will be conceded, indeed serious doubts and great incredulity as to its practicality were expressed. But the promoters of the plan have gone on, confident that the farther it was pursued and the better it was understood, the more hopeful the view that would be taken of its outcome. The central theme around which the whole is grouped is the unity of science. This theme is carried through from the center into details which shall include every branch of learning. With it is associated the discussion of the conceptions, progress, relations and problems of the various sciences. The details of the plan as finally worked out are found in the programs of the congress, which so many readers of The Popular Science Monthly have probably seen, that only a

brief *resumé* will be necessary. A general address on the work of the congress will be followed by discourses on the inner unity of seven great divisions of knowledge. These seven meetings will be followed by others in twenty-four departments in each of which will be set forth the fundamental conceptions of the various branches, and the progress of each during the nineteenth century. The remaining days of the congress will be occupied with meetings, each lasting three hours, for discussions of the present problems of each science and of its relations to cognate branches.

A necessary condition to success, which was had in view from the beginning, was that the leading addresses should be given by the most eminent representatives of every branch of science whose attendance at the congress could be secured. This must be regarded as one of the novelties of the scheme, calculated to heighten its interest. But the problem of realizing it was no easy one. To invite all eminent investigators of various countries was not a difficult matter—no doubt it has been done in the case of many a congress—but it would obviously be impossible to bring together even one representative of every branch of science by merely extending this invitation. The difficulty was heightened by the fact that two principal addresses were to be delivered in each of the great branches. Only three hours being allotted to each branch, the number of addresses could not be increased. After a careful consideration of the exigencies of the situation it was found impracticable to extend the number of individual branches that could be treated in a single week beyond a limit which might approximate to 130. By frequent additions and exclusions as the development of the scheme was worked out the maximum was found to be 128. It seemed that the most satisfactory result would be reached by having sixteen simultaneous meetings, each for the discussion of a single branch, on each half-day. The number of available days being four, it would thus be possible to arrange for 128 meetings of three hours each. The limitations thus imposed rendered necessary the exclusion of many important branches of science from the list of subjects to be specially treated. The best that could be done was in each case to give preference to branches of such interest or so widely cultivated that it was not difficult to find speakers to treat them.

Much having been written on the adopted scheme of classification and its defects, a word on this subject may not be out of place. I do not suppose that any one concerned would for a moment claim that the field of knowledge could be separated into exactly seven divisions, neither more nor less—or that there are twenty-four separate departments of knowledge, and 128 branches of sciences of sufficient importance to be separately treated. Nor is it important whether the scheme of classification is or is not ideally a good one. The main object was

to obtain a grouping of the subjects and speakers which would have sufficient logical symmetry to enable the whole scheme to be understood and carried into practical execution. These ends have been attained, and having been attained the discussion of the logical merits and demerits of the scheme may be left to those interested. I shall only mention one feature of the classification which more than any other may have struck the reader of the program as a departure from a usage consecrated by time, and presumably convenient in practise. In classifying books and in organizing academies of science it has been common to group the mathematical and physical sciences together, putting pure mathematics in the same class with physics. This practise is very natural because of the close association in the development of these two branches. The same men frequently took part in both, and there was formerly a sharp division between the physical sciences which need mathematics, and the biological sciences which do not. But in the program, mathematics is put with philosophy under the division of normative science. No one will contest the correctness of this course in an ideal system, since philosophy and pure mathematics both have the fundamental qualities designated by the term 'normative.' It would also have been logically misleading if the organizers had at the present time placed mathematics among the physical sciences, because we should thereby be ignoring that mathematical methods and nomenclature are being introduced into a constantly increasing mass of biological science and that, as knowledge advances in precision, it must continually become more and more mathematical in form.

To recapitulate—the congress will hold only one meeting as a single body; and its first act on the second day will be to divide itself into seven grand divisions, in each of which will be treated the unity of one of these divisions of knowledge. These 'divisions' will next separate into twenty-four departments in each of which will be treated the fundamental conceptions and the progress of knowledge in these departments during the nineteenth century. The congress will then be divided into about 128 sections, in each of which the present problems of the special science and its relations to other sciences will be treated. The plan of the congress thus involves the preparation and reading of some 300 principal addresses by eminent investigators from various parts of the world on the unity, conceptions, history, relations and problems of the main subdivisions of knowledge.

It will be seen that one important point in which the congress deviates from the familiar type is that it is not primarily a meeting for the reading and discussion of scientific researches. The publication of new results is not aimed at, but rather the communication of ideas which will result in stimulating research in the future. Breadth of treatment is the characteristic of the plan. Still, there is one arrangement

now to be mentioned which will admit of reading or discussing subjects of interest, though technical in character. After assigning due time for the reading of the principal papers, and making the necessary arrangements, there will remain about an hour, perhaps a little more, in each sectional meeting, for such intercommunication of ideas as will promote the object of the congress. This hour will be filled by 'brief communications'—of which it is supposed the average or ordinary length may be ten minutes. The conditions will be of so varied a character in the different sections that it is impossible to lay down unchangeable rules, or make uniform arrangements for these discussions. Everything must depend upon the number in attendance who desire to speak, and their respective wishes. An effort has been made to obtain in advance promises from five or six who expect to be present to make such communications. It is quite likely that, in many cases, the requisite number will not be prepared beforehand. But it is not to be expected that two elaborate scholarly papers of wide scope will be listened to without some one being able to add a few ideas. It should, however, be emphasized that discussions of the papers in the ordinary sense such as are usual in scientific meetings, is not expected. Many, perhaps most, of these papers will have involved weeks and months of preparation; and it is scarcely respectful to assume that an off-hand discussion of them, without previous knowledge of their contents, will be possible. But this will not preclude expression of the ideas to which the hearing will undoubtedly give rise in the minds of the auditors.

As already intimated, no attempt has been made to place absolute limitations on the themes of these brief communications. It has been deemed wise to prepare discussions which will promote the general object of the congress, and to ask that technical papers be on subjects of wide general or professional interest.

Another new feature is that the program of the congress not only includes all the great branches of science in its scope, but several subjects of wide human interest which we are accustomed to regard as lying outside the boundaries of exact knowledge. History, art, diplomacy, religion, education—and indeed most of the great fields of human activity are brought into the plan. An effort is thus being made to correlate not only what has been in the narrow sense of the term called science, but other great subjects which admit of the treatment proposed in the general plan of the congress.

An idea of the extent to which there will be a bringing together not only of the sciences but of representatives of wide fields of human activity is also shown by the men who are to treat them. For example, it is expected that the subject of national administration will be treated by the eminent author of the 'American Commonwealth,' unless the

exigencies of his important duties at home prevent his attendance, a result which now seems unlikely. Baron d'Estournelles De Constant, the leader of the arbitration group in the French Chamber of Deputies, whose party has achieved so splendid a triumph through the completion of an arbitration treaty between France and England, is to deliver the principal address in the section of international law. Signor Attilio Brunialti, councillor of state, at Rome, will be the principal speaker on the subject of constitutional law. The history of the christian church will be treated by Professor Jean Réville, of the faculty of protestant theology at the University of Paris, and also by Professor Harnack, of the University of Berlin. Other foreign speakers in the division of historical sciences are Professor Ettore Pais, director of the National Museum of Antiquities at Naples, Professor Arminius Vambéry, the Asiatic traveler and oriental scholar of the University of Budapest, and Professor Henri Cordier, of Paris.

The sections of biology and medicine are especially strong. Among the expected foreign speakers are Professors Hugo De Vries, of Amsterdam; Oskar Drude, of Dresden; Alfred Giard and Yves Delage, of the Sorbonne; Sir Ronald Ross, of Liverpool, and Professor Celli, of Rome, the two last being leaders in discovering the causes of malaria. Sir Lauder Brunton, of London, Professor Kitasato of Japan, the eminent bacteriologist, Sir Felix Semon, physician extraordinary to the King, and Professor Escherich, of Vienna, are among the foreign medical men. Professor Hugo de Vries will treat the subject of the origin of races, while Wiessner, Drude, Giard, Fürbringer and Waldeyer will represent their several branches.

Our mathematicians will be afforded an opportunity to meet a brilliant trio from the French Academy of Science,—Darboux, Poincaré and Picard. Our astronomers will greet with warmth Dr. Backlund, director of the Pulkowa Observatory and Professors Kapteyn and Turner. Sir William Ramsay and Professors Moissan and Van't Hoff will be among the speakers on chemistry. Professor Arrhenius is to set forth his new and striking views on the more mysterious phenomena of cosmical physics, and Sir John Murray will be the principal speaker in the section of oceanography.

That every specialist in research will derive both pleasure and profit by withdrawing his attempts for a brief period from his own province and listening to what his fellow investigators in widely different specialties have to say in regard to the problems and relations of their several fields of study is too obvious to need enforcement. But we should err in confining the benefits thus arising to actual suggestions. We must recognize the historic fact that modern science really began, not with investigations, but with the ideas which were necessary to the beginnings of investigation. Even to-day an in-

genious philosopher who propounds an entirely faulty system may be an important factor in the advance of truth through the sharpening of the mental faculties of his critics by analyzing his system, pointing out its defects, and either correcting his results, or putting them into proper shape. Since the time of the schoolmen it has been recognized that the analysis of fallacies is one of the best methods of discipline in the art of correct reasoning.

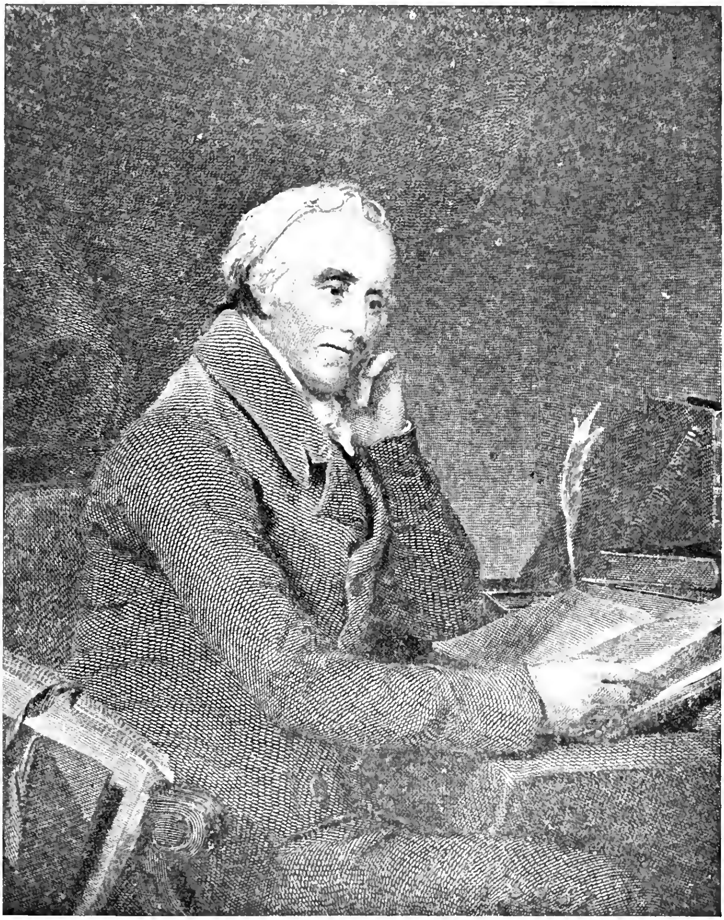
The arrangements made by the authorities of the fair for enabling the scientific men of our country to avail themselves of the advantages of this remarkable assemblage and to listen to its discussions have been of the most liberal kind. No admission fee is required other than that to the fair itself, and the meetings are open to all known to be interested, so far as room can be found. The attendance of members of national scientific societies and professors in colleges and universities and scientific men generally is especially desired. Whether room can be found for all who wish to attend can not be known until the wishes of more are heard from. Subject to this condition, every professional scholar and scientific teacher or investigator is welcome to avail himself of an opportunity which may not recur in a lifetime.

Monument erected at Washington by the American Medical Association in Honor of Benjamin Rush.

THE PROGRESS OF SCIENCE.

BENJAMIN RUSH.

THERE was unveiled at Washington on June 11 a monument erected by the American Medical Association to the memory of Benjamin Rush. The principal address was made by Dr. J. C. Wilson, and President Roosevelt received the monument on behalf of the government. It stands on the grounds of the Naval Museum of Hygiene, and, as the accompanying illustration shows, is of imposing dimensions. The bronze



Benjamin Rush

statue was designed by Mr. Perry and the pedestal by Mr. Metcalf. The American Medical Association has thus completed an undertaking begun more than twenty years ago, and has erected a worthy memorial to perhaps the most distinguished American physician.

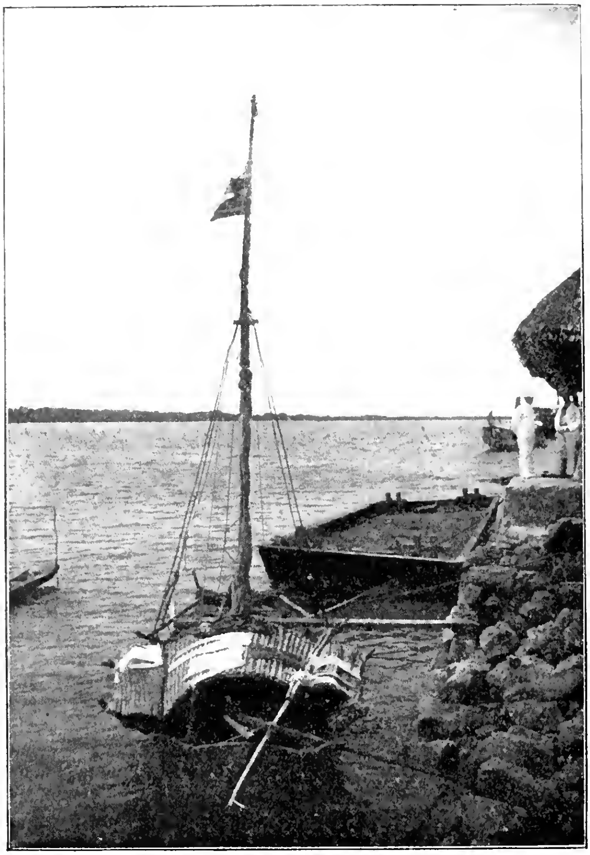
It is probably known to most readers of this magazine that Rush was an eminent Philadelphia physician and a signer of the declaration of independence, but a few words may be said in regard to his career. Rush was born in 1745 and educated at Princeton and Philadelphia, and later studied at Edinburgh, London and Paris. On returning to Philadelphia, then the chief intellectual center of America, he identified himself at an early age with its medical and political activities. It may be largely due to Rush that Philadelphia retained until quite recently the leadership in medical education and practise. He was appointed professor of chemistry at the College of Philadelphia, and when the Medical Department of the University of Pennsylvania was established in 1781 was elected to the chair of medicine. He was one of the founders of the College of Physicians and was an officer of the American Philosophical Society from 1770 to 1801. In the meanwhile he had taken an active part in the political movements leading up to the revolution. He was a member of a committee of two who reported to the Provisional Conference at Philadelphia on the expedi-

A Gutta-percha Tree, District of Zamboanga, Mindanao.

ency of the declaration of independence, and is supposed to have written the report, much of which was incorporated in the declaration. He was a surgeon-general in the war of independence, but resigned after two years, owing, it is said, to differences with Washington in regard to hospital stores. Thereafter he devoted himself to medical work and writing, but retained wide interests, advocating, among other things, the abolition of slavery, temperance, the higher education of women, international arbitration and religious liberty. His services at the time of the epidemic of yellow fever in 1793 and his account of it gave him a wide reputation, though he was on the wrong side of the question in a dispute with his fellow physicians as to the cure of the disease by blood-letting. Probably, however, his work on behalf of the insane was his most important service to medical science. He suggested detached cottages for the care of the insane, objecting to the confinement of lunatics in cells as early as 1789. Rush died in 1813.

Dr. Wilson in his address at the unveiling of the monument said: "Nearly a century has passed since Benjamin Rush was gathered to his fathers. To his contemporaries he was a man not unlike other men, having his virtues and his faults, a good citizen, a skillful physician, kindly, courteous, benevolent, and having on occasion much fight in him. He was even known to

A RUBBER VINE, WESTERN MINDORO.



CHINESE TRADING BOAT, COLLECTING GUTTA-PERCHA AT PARANG PARANG.

have some fame in distant lands, chiefly because of a wonderful, clear narrative of the bilious yellow fever of 1793 which he had written. To us, who see him through the vista of one hundred years, he stands, not, indeed, the most conspicuous figure of a time brilliant with heroic men and deeds, but great among the greatest, and certainly the most striking and impressive figure of the medical life of America at that period or any period since."

GUTTA-PERCHA AND RUBBER IN THE PHILIPPINES.

IN the recent report of the superintendent of the Government Laboratories in the Philippine Islands, to which we have already called attention, a good deal of space is given to the question of the production of gutta-percha and rubber in the islands. Owing to the recent development of applied science, these substances have become very widely used, and there is danger lest the supply become exhausted. It is indeed certain that this will happen unless the production is artificially guarded and increased. Thus in the Philippines gutta-percha is collected by the savage tribes, who cut down the trees and collect perhaps one fortieth of the gutta-percha they contain. The native collectors sell it for about \$5 per picul of 168½ pounds; the middlemen sell it to the Chinese

in the export towns for $20 to $40, and it is then sold at Singapore for from $50 to $75. It is said that the production of gutta-percha could be greatly increased by economical methods of extraction, and that the native forests are likely to become exterminated unless protected. It appears that the example of the Dutch government, which has planted a million trees in Java, could be with advantage followed in some parts of the Philippine Islands.

No rubber-producing trees have been found in the islands, but there are two species of vines widely distributed, both of which produce a good grade of rubber. This is collected by the Moros, but naturally in a very wasteful manner. A good deal could be accomplished in conserving this natural supply, but the future of the industry in the Philippine Islands doubtless depends on following the example of India, Burmah, the Malay States and Java, where scientific work on the cultivation of the trees was first taken up by the governments, and private cultivation was then widely and profitably introduced.

SCIENCE, WAR AND POLITICS.

It is somewhat curious to compare the concentration of popular interest on war and politics with the common ignoring of science, when we remember that the progress of science has exerted more influence on the course of history than all the armies and political parties of the nations of the world. The entire democratic movement of modern times is directly due to the applications of science, which have made it possible for all to enjoy the advantages that were formerly confined to a few. Any given war or political movement is due to conditions that science has created. Even the popular interest in such matters is only possible through the steam-engine, the telegraph and the printing press. The intellectual and moral attitude of the people is as directly dependent on science as are their material surroundings. The ideas of the origin of species are more potent than the consequences of the wars of the nineteenth century in which some twelve million men were killed.

It is not exactly easy to say why there is more interest in a political convention than in a meeting of the American Association for the Advancement of Science, why the newspapers are read by millions while a scientific journal is read by thousands. The community of interest, even the party spirit, which the newspaper makes possible, has a function for society similar to that of the church. But the direction of this interest appears to be more or less artificial. If the newspapers would for a time devote most of their space to scientific, artistic and literary matters and if people would talk and think these things perhaps they would prove to be as good bonds of union as a murder or even a war. It may be said that the results of science can not be understood by the ordinary man, and this is of course true; but neither can he understand the plans of a military campaign nor the motives of a party leader. The stability of science might lead to an ultimate understanding of its great principles by large groups, and there are numerous matters easily explained which would maintain an interest if once excited. For example, why is not information in regard to the advance of our knowledge of the warfare between disease germs and man as full of personal and dramatic interest as a foreign war.

To a certain extent the supremacy of science and art does assert itself. The names of Sig. Marconi and Mme. Curie and what they stand for are better known in this country than the names and policies of the leaders of the governments of Italy and France. Yet the work of the two people mentioned is by no means so important and perhaps not even so interesting as that of others. An even juster view than that of distance is given by time.

No scientific man and his discovery have been applauded as were Admiral Dewey and his victory, yet a century hence scientific men of the present period will be mentioned more often than our military and political leaders. Darwin's work is more effective and permanent than that of any contemporary soldier or statesman; it is probably much better known throughout the world and will be so increasingly.

If it were but possible to direct the mind of the crowd to science, an interest would be created which would be self-perpetuating. The minor events of war and politics would be subsumed under broader principles. A nation whose chief interests were in science would need no army and but little government. It would be prosperous beyond measure in peace and would be invincible in war.

SCIENTIFIC ITEMS.

We note with regret the death of Dr. Isaac Roberts, eminent for his work in astronomy, especially for his study of star clusters and nebulæ, and of Sir John Simon, K.C.B., former vice-president of the Royal Society and president of the Royal College of Surgeons, well known for his important services on behalf of the public health.

A medallion in memory of the late Sir George Gabriel Stokes, which has been erected in the north aisle of the choir of Westminster Abbey, was unveiled on July 7 by the Duke of Devonshire, chancellor of the University of Cambridge, and formally transferred to the authorities of the Abbey. Addresses were made by Sir William Huggins, Lord Rayleigh and Lord Kelvin.—A public meeting has been held at Bury, England, to celebrate the bicentenary of the birth of John Kay, of Bury, inventor of the fly-shuttle, to promote a public fund for the erection of a statue in memory of the inventor and to institute scholarships.

The Paris Academy of Sciences has decided to award its LeCompte prize of the value of $10,000 to M. Blondlot for his researches on the so-called n-rays.—Dr. Robert Koch has been made honorary professor of the University of Berlin as well as a member of the Academy of Sciences in succession to Virchow. There are only two other similar positions at Berlin, the one held by Professor Auwers, the astronomer, the other by Professor Van't Hoff, the chemist.—Dr. C. H. Tittman, chief of the Coast and Geodetic Survey, has left Washington for Alaska, where he will meet Dr. W. P. King, chief astronomer of Canada, in order to mark the boundary line between Alaska and Canada in accordance with the decisions of the commission that met last year in London.—Mr. Bailey Willis, of the U. S. Geological Survey, has returned from China, where he has been making geological explorations under the auspices of the Carnegie Institution.

It is announced that Dr. Harry Tevis will establish in San Francisco an aquarium in honor of his father, the late Lloyd Tevis, which will be the finest institution of the kind in the world, the cost being $3,000,000 to $4,000,000. The aquarium will, it is said, be built in Golden Gate Park. Mr. John Galen Howard, supervising architect of the University of California, is preparing the plans.—The Schunck Laboratory, bequeathed to Owens College by the late Dr. Schunck, who had in his lifetime endowed the college with £20,000 on behalf of chemical research, has been removed from his residence at Kersal and rebuilt in the college precincts as nearly as possible in its original form. It comprises two floors and a basement, with the most modern appliances, also a valuable library and a collection of coloring matter, natural and artificial.

The Honorable Arthur J. Balfour, Prime Minister of England,
President of the British Association.

THE
POPULAR SCIENCE
MONTHLY.

OCTOBER, 1904.

A TRAVELER'S VIEW OF THE BRITISH ASSOCIATION MEETING.

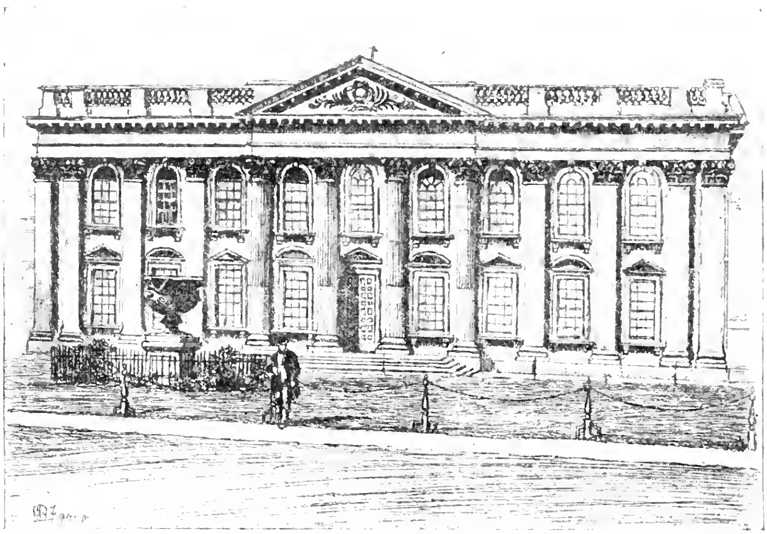
BY DR. HENRY S. PRITCHETT.

PRESIDENT OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

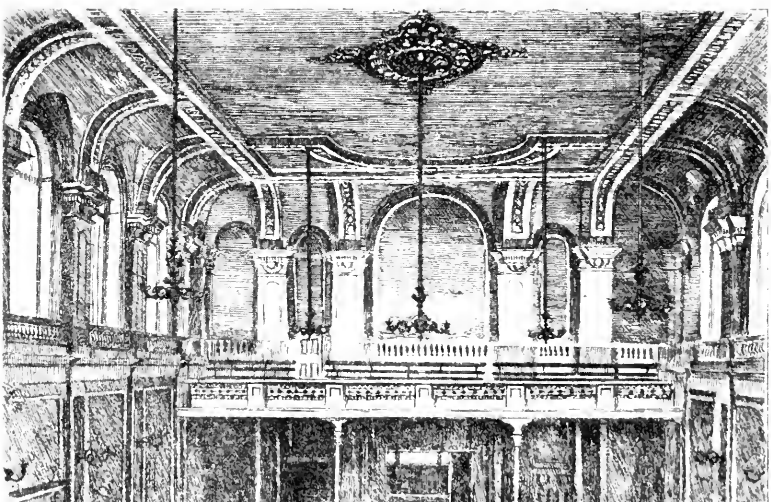
THE meetings of the British Association for the Advancement of Science must always have great interest for Americans; and not alone for scientific men, but for all students of the larger national movements and sources of power in the two great English-speaking countries.

The meeting just closed (August 17–23), held in the old university town of Cambridge, brought together a large number of persons connected with or interested in the science of Great Britain. The registration reached nearly 3,000. In these days when the meetings of the American Association, even under the admirable efforts which have been put forth for some years, have shown a tendency to dwindle, this fact alone is one of interest and of significance to Americans. Two reasons combined to make the attendance at the Cambridge meeting unusually large, first the attractions which naturally belong to this charming old university town, and secondly the presence of the prime minister of Great Britain as president of the association.

To one familiar with the history of our American Association and with the conduct of scientific work in the United States this fact—the presence and active participation of the head of the government—was perhaps the most curious and interesting feature of the meeting. Science and politics have seldom had in our country that close association which one finds in England, Germany and most continental countries. Fancy President Roosevelt taking a week to preside over the meetings of the American Association, to deliver an address and



SENATE HOUSE, WHERE DEGREES WERE CONFERRED.



INTERIOR OF THE GUILD HALL, WHERE THE PRESIDENT'S ADDRESS WAS GIVEN.

The Illustrations are from 'Memorials of Cambridge,' by J. Le Keux and C. H. Cooper and from 'Cambridge' by J. W. Clark.

to participate in its discussions! Or imagine Mr. Speaker Cannon as president of the section of economics and taking a real part in the debates! This lack of touch between scientific men and politicians in our country as compared with the older European countries is due to several causes. The high places in political life are in the older nations mainly in the hands of university men (a process that is going on with us), but more than this the profession of politics in them is not incompatible with the spirit and work of the scholar.

Jefferson more than any other president was a representative of the science of his time. During a part of his first term he was president of the American Philosophical Society and set apart some of the rooms in the executive mansion for the study of fossils, particularly of those of mammoths. It is safe to say that no other president since his day has found the time to give any serious thought to the encouragement of science or of education as a part of national development.

Perhaps the criticisms which Jefferson called down upon himself by his scientific tendencies have not served to encourage other presidents. His geological studies were pointed to, about the time of the Louisiana purchase, with great bitterness by his critics as indicating those radical and godless tendencies which culminated in the act of purchase. There is a poem of William Cullen Bryant on this transaction which is addressed to Jefferson and which begins

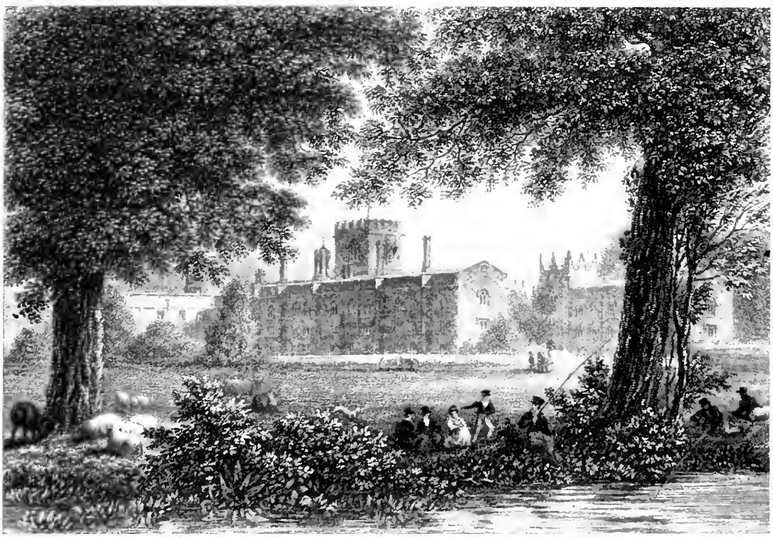
> Go wretch, resign the presidential chair;
> Reveal thy secret purpose, foul or fair;

In the course of the poem 'frogs' are significantly made to rhyme with 'Louisianian bogs.' The fact that the poet was but thirteen at the time may be taken as a measure of the sharpness of the criticism which awaits a president who compromises himself by too great intimacy with science. It is easier, if not safer, for a president to look after the post offices and let science take care of herself.

Mr. Balfour himself did not altogether escape this sort of criticism. His address had for a title 'Reflections Suggested by the New Theory of Matter.' The opposition papers were not slow to suggest that the prime minister and practical ruler of a great commercial country could spend his time to better advantage than in discoursing transcendental philosophy to admiring audiences of scientists!

The critics were so far right in terming Mr. Balfour's address philosophical rather than scientific. By disposition and by education Mr. Balfour is a speculative philosopher rather than a man of science, and his address leaned strongly toward that mildly pessimistic attitude of the speculative philosopher, which balances in a nice way this and that conclusion, and goes no whither.

The address sketched a brief comparison between the scientific conception of the physical universe to-day and that of one hundred years ago. It was remarkable in this respect that a man so full of other work, as Mr. Balfour must be, should be able to frame such a statement without committing errors of fact of a serious sort. As an analytic review it had no great value (notwithstanding the one or two ingenious points brought forward) on account of the speaker's lack of expert knowledge in physics and on account of the constant assumption of a position entirely apart from and unlike that of the physical investigator. The address could be called on the whole clever, interesting and suggestive from the philosophical standpoint, and to have

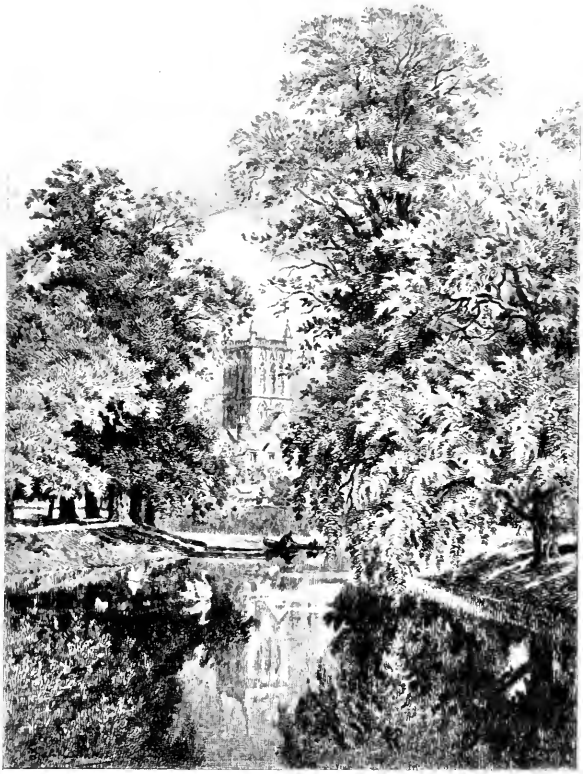


JESUS COLLEGE, FROM THE MEADOWS.

presented such a paper is an evidence of great intellectual alertness and ability on the part of a man whose hands are full of practical business.

The occasion of the presidential address on the evening of the first day was the most interesting event of the meeting and the one which brought together the most interesting audience. Mr. Balfour read his address, explaining that in this he followed precedent, although speaking was easier to him than reading. He spoke with a clear, pleasant voice and in a perfectly natural and easy manner. His delivery throughout was most effective. On the platform beside him sat many of the best known men in British scientific circles, the veteran Lord Kelvin occupying a place to the left of the speaker, and looking like an idealized version of Uncle Joe Cannon.

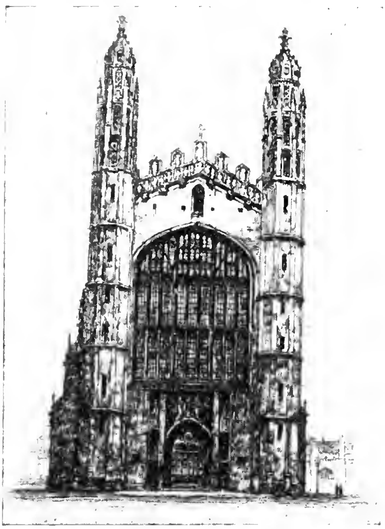
There is one custom always observed on such occasions, which the American learns to recognize after a while as a part of English politeness, but which never ceases to amuse him. I refer to the speeches made in moving a vote of thanks after an address. This custom seems an invariable one: at business boards, at scientific gatherings, at charity meetings the chairman or the speaker is always formally and specifically thanked. The process is as follows: First a distinguished



THE CAM, NEAR TRINITY COLLEGE, WITH THE TOWER OF ST. JOHN'S COLLEGE CHAPEL.

member of the audience (the more distinguished the better) moves a vote of thanks in a speech of greater or less length and full of personal compliment for the speaker; then a second member of the audience of equal distinction, if possible, seconds the resolution in a speech in which he tries to mention all the good points not mentioned by the first. A vote is then taken. It goes without saying that the resolution passes unanimously. The most amusing part of this naive proceeding comes when the original speaker rises to reply to the vote of thanks. The mover of the vote of thanks on the occasion of Mr. Balfour's Cam-

bridge address would naturally have been the chancellor of the University of Cambridge, the Duke of Devonshire, but owing to the political changes of the last eighteen months the duke and the premier could not very comfortably meet on the same platform. The vote was therefore moved by the vice chancellor and seconded by the lord mayor of Cambridge. In his reply Mr. Balfour acquitted himself admirably, showing not only the ability of a polished speaker, but acknowledging the praise of his address in modest and fitting words.



King's College Chapel.

On the following morning visitors in section A (which in the British Association includes both mathematics and physics) had the pleasure of hearing Mr. Balfour in the opposite rôle, as the mover of a vote of thanks to Professor Lamb after the delivery of his address as president of the section; a part which the prime minister filled with equal grace and skill and with as much seriousness as can be made out of such a naive proceeding as this process must be. Mr. Balfour's presidency of the association was no sinecure. He met all its duties most faithfully and carried out the business of the president with admirable tact. He appeared at the meetings of various sections, took part in the discussions of some of them as in the section of economics, and threw himself heartily into the social duties of the meeting. On the evening of the general reception to the members and visitors given in the splendid halls of Trinity College (Mr. Balfour's own college) he is said to have shaken hands with more than three thousand persons, and up to the last belated guest his smile was as cor-

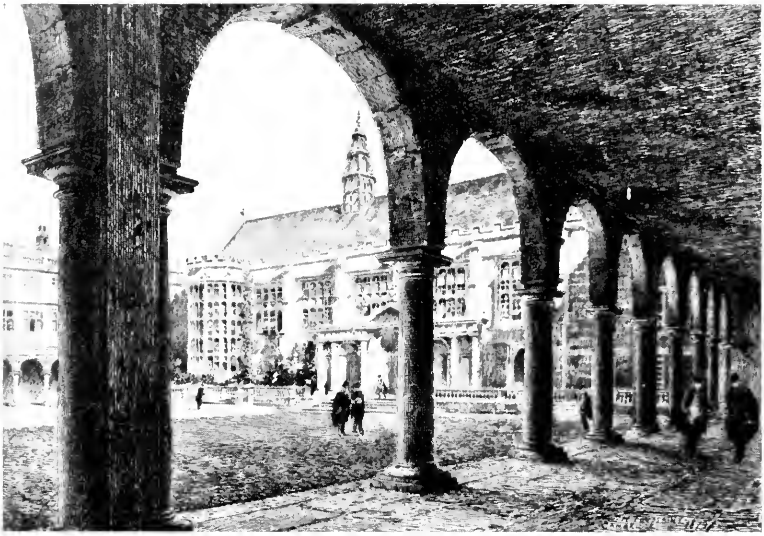
Interior of King's College Chapel.

dial and his handshake as hearty as at the beginning. For each member, and particularly for all visitors from outside England, he had a kindly word, and a greeting which while most hospitable was never overdone; which carried the pleasure of a friendly welcome without losing at any moment the stamp of good breeding. Except perhaps President McKinley, I have never seen a man in public station who could receive so many persons in a public reception and so successfully make each one feel that he had been given a special welcome. As an American who has seen much of political life remarked, 'A man who can shake hands

PETERHOUSE.

like that would be a successful politician in any country.' Mr. Balfour was in fact an ideal president of the association, democratic, yet dignified. He left on those who saw him for the first time the impression of a man who had not only intellectual power, but also one who combined with this good breeding, good nature and common sense.

A very interesting comparison between the American and the British Association could be found in a study of the sectional addresses and other leading papers of the one as contrasted with the other. In such a comparison the American would find little to minister to national vanity. The presidents of the sections in the British Association are almost always men of assured scientific standing and reputation. Their audiences include many of the best known men of science in England. The addresses are prepared with more care and are generally given in a more interesting and effective manner. The occasion



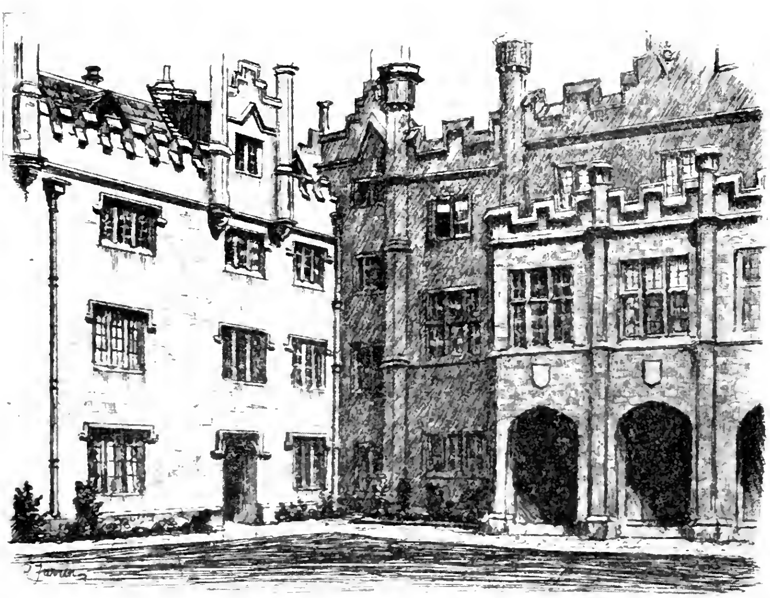
Neville's Court, Trinity College.

means more to a speaker than it does with us, at least during the last fifteen years since the tendency to segregate into special scientific societies has been so marked. It would be difficult to bring together in America any such group of mathematicians and physicists as sat with Professor Lamb on the platform on Thursday morning while he read his presidential address before section A. The vote of thanks after the address was moved by Mr. Balfour and seconded by Lord Kelvin.

Nevertheless admitting all this, it is evident to one who listens to papers in both associations that the essential difference in the character of the papers presented at the two meetings lies in the difference in scientific training and habits of scientific work in England and in America; and one can not but be struck with the fact that the scientific training and methods of work in America are far more German than English. While the addresses in American scientific societies lack the philosophic interest and charm which characterize many of those given before the British Association, the authors of these papers are trained to go more directly at their problems, laying bare the difficulties and even the failures of the method or the process, but passing on to some point of vantage. One finds in many English scientific papers a clever use of words and terms; a tendency to philosophize instead of doing the hard work of investigation; a disposition to deal charmingly, sometimes half humorously, with the results and observations costing great labor; and in the end the whole subject left in a sort of agreeable haze in which one seems to have traveled a long distance without going any whither. The method of attack adopted is

somewhat akin to that of the modern military practice, under which frontal attacks are abandoned in favor of a less direct method of assault. One sees in English scientific papers a greater tendency to attack by the flank than in America or Germany; a somewhat readier disposition to be satisfied with a general statement of facts already known rather than the concentration of effort on particular problems which need to be cleared up. All of which simply means that the methods of education and of national life in England have not brought into existence a large army of disciplined students of research such as one finds, for example, in Germany.

The fact that physics and mathematics are still retained in one section in the British Association is not without significance. The necessary connection between the two was many times referred to in the addresses and papers of the section. Notwithstanding this there was more than one reference to the fact that mathematics, as taught in the universities and colleges, is seldom grasped by the student so that it becomes a facile tool in his hands. This is a disappointing fact in our present day teaching on this side the Atlantic no less than in England. Why is it that mathematics, the oldest of the sciences, should lend itself less readily as an instrument of research or of practice than chemistry or physics? Is it because we fail to use the laboratory method in mathematics? or because we are still tied to the methods of the past? or is it due in part to the fact that too little time



FIRST COURT OF SIDNEY SUSSEX COLLEGE.

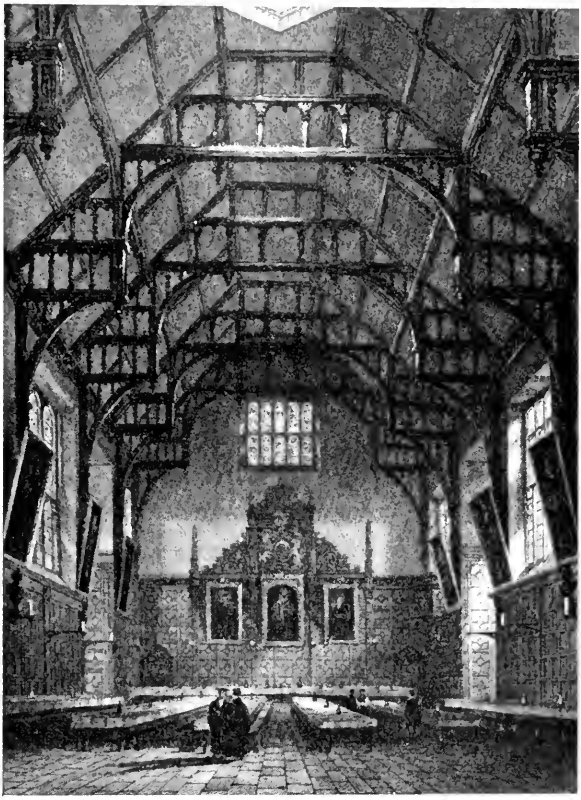
is given to learning elementary mathematical concepts before rushing on to complicated theory and partly perhaps to the fact that those who teach mathematics in the colleges are almost always those who never have occasion to apply it?

The groups of individuals who made up the small army of 2,800 persons registered at the Cambridge meeting were varied. First of all there were the well-known men of science like Lord Kelvin, Lord Rayleigh, Professor Thomson, Professor Forsythe, Professor Dewar and many others. Next in interest came the large group of younger men, probably mostly from Cambridge University, who were to be seen in many of the sections. The great body of associates was made up, as is the case in meetings of the American Association, of the wives, daughters and friends of the members. The women associates, as in America, were in greatest evidence in the social functions, the excursions and in a few of the sections, particularly in that devoted to educational science, the last section organized in the British Association. On Thursday morning before this section Dr. Kölössy, of Budapest, read his paper before an audience of about fifty men and three hundred women.

Considering the present relation of public education in England to the church it was quite natural that the president of this section should be the Lord Bishop of Hereford, himself a teacher of experience. The papers before this section were however devoted to elementary educational questions rather than to problems of educational science, and the discussions which were had, particularly when they touched on such subjects as the education of women or the function of manual training, sounded curiously like those to which we were accustomed in the United States twenty-five or thirty years ago. The questions which occupied the larger part of the time were in large measure local and concerned themselves with details of educational work rather than with fundamental underlying theories of education. This also is perhaps to be expected in a country which has placed its work of education in large measure in the hands of a single section of the protestant church.

To an American visitor the large number of curates of the established church who appeared in the meetings of the association formed a pleasant picture. This presence does not mean any widespread study of science on the part of the clergy, but is rather a natural outgrowth of the association of university men. A large proportion of those who graduate at the universities enter the church, and it is to be expected that in a gathering which brings together distinguished scientific men, as well as those interested in a general way in science, there should be a number of the clergy. Their presence also serves to emphasize another feature of the association which the American is likely to overlook, and this is the fact that the British Association finds its strength

and its influence, in large measure, in the social soil into which it sends its roots. Social influence is one of the most powerful factors in English life and one of the most powerful in politics. The British Association gains much of its prestige from its social and political setting, and in directing social and political power no one interest is so strong as that of the established church.



INTERIOR OF THE HALL, TRINITY COLLEGE.

Looking at this great gathering from the standpoint of an interested outsider, the American who studies it can not but be impressed by its possibilities for usefulness in scientific and in national development. It is a fine thing to bring together the representatives of science, of politics, of religion and to have them meet face to face a large body of men and women drawn from the most intelligent homes in the kingdom. The general effect of all this is somewhat neutralized by the social machinery through which it works, but allowing for all this it still seems evident that such a gathering is a source of great intellectual stimulus both to the scientific men and to the public. It is no

small thing to present a paper in a section where so many famous men sat as could be seen in section A at almost any time of its sitting. And it is no small credit to British men of science that this great gathering is preserved from year to year in undiminished enthusiasm.

Is it possible to make of the American Association such a gathering, or rather to restore to it its representative character? May we expect to gather to it the well-known men of science, the ambitious students and the scientific public?

Many things make against such a result in America which are here favorable to it. The small distances to be traveled in Great Britain make it easy and cheap for any member to come to the meetings. Again the British Association flourishes and gains its influence in the midst of a social régime entirely differnt from that which holds in our country. But in addition to all this are the differences in scientific training which prompt the American investigator, whether in pure or applied science, to prefer the society of his fellow experts to any gathering of a general character however attractive it may be by reason of the presence of scientific, political or social celebrities. That which makes the success of the British Association possible is at once the weakness as well as the strength of British science, and the influences which make these meetings what they are are intimately connected with the educational and social conditions which exist in England.

But if there is anything which would bring back once more to the American Association its old-time prestige and its old-time influence, it would be some such devotion to the cause, which the association represents, as has been shown by many of the leading men of science in England. Of all this group perhaps no other one has done so much as Lord Kelvin. For half a century this splendid old man (loved no less for his sweetness than honored for his genius) has been a prominent figure at these annual gatherings. Year after year he has not only presented his own brilliant contributions and taken his part in the discussions, but there has scarcely been presented in all these years, in the subjects in which he stands preeminent, a worthy paper by a struggling younger man whom this Nestor of British science has not encouraged by his words of praise or of friendly advice given in the most kindly and helpful spirit. The example and influence of such a man are beyond praise, and however we may criticize English science, and English methods of education, we may well hope to learn of her many things so long as she produces men like Kelvin. If anything can make of the American Association a new center of inspiration for younger men, a fresh source of popular education, a means of closer union of our scientific interests, it will come only as the result of some such unselfish service as Kelvin's on the part of the best known men of science in America.

REFLECTIONS SUGGESTED BY THE NEW THEORY OF MATTER.

BY THE RIGHT HONORABLE ARTHUR JAMES BALFOUR,

PRESIDENT OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE meetings of this great society have for the most part been held in crowded centers of population, where our surroundings never permit us to forget, were such forgetfulness in any case possible, how close is the tie that binds modern science to modern industry, the abstract researches of the student to the labors of the inventor and the mechanic. This, no doubt, is as it should be. The interdependence of theory and practise can not be ignored without inflicting injury on both; and he is but a poor friend to either who undervalues their mutual cooperation.

Yet, after all, since the British Association exists for the advancement of science, it is well that now and again we should choose our place of gathering in some spot where science rather than its applications, knowledge, not utility, are the ends to which research is primarily directed.

If this be so, surely no happier selection could have been made than the quiet courts of this ancient university. For here, if anywhere, we tread the classic ground of physical discovery. Here, if anywhere, those who hold that physics is the true *scientia scientiarum*, the root of all the sciences which deal with inanimate nature, should feel themselves at home. For, unless I am led astray by too partial an affection for my own university, there is nowhere to be found, in any corner of the world, a spot with which have been connected, either by their training in youth, or by the labors of their maturer years, so many men eminent as the originators of new and fruitful physical conceptions. I say nothing of Bacon, the eloquent prophet of a new era; nor of Darwin, the Copernicus of biology; for my subject to-day is not the contributions of Cambridge to the general growth of scientific knowledge. I am concerned rather with the illustrious line of physicists who have learned or taught within a few hundred yards of this building;—a line stretching from Newton in the seventeenth century, through Cavendish in the eighteenth, through Young, Stokes, Maxwell, in the nineteenth, through Kelvin, who embodies an epoch in himself, down to Rayleigh, Larmor, J. J. Thomson, and the scientific school centered in the Cavendish laboratory, whose physical speculations bid fair to render the

closing years of the old century and the opening years of the new as notable as the greatest which have preceded them.

Now what is the task which these men, and their illustrious fellow-laborers out of all lands, have set themselves to accomplish? To what end led these 'new and fruitful physical conceptions' to which I have just referred? It is often described as the discovery of the 'laws connecting phenomena.' But this is certainly a misleading, and in my opinion a very inadequate account of the subject. To begin with, it is not only inconvenient, but confusing, to describe as 'phenomena' things which do not appear, which never have appeared, and which never can appear, to beings so poorly provided as ourselves with the apparatus of sense perception. But apart from this, which is a linguistic error too deeply rooted to be easily exterminated, is it not most inaccurate in substance to say that a knowledge of nature's laws is all we seek when investigating nature? The physicist looks for something more than what by any stretch of language can be described as 'coexistences' and 'sequences' between so-called 'phenomena.' He seeks for something deeper than the laws connecting possible objects of experience. His object is physical reality; a reality which may or may not be capable of direct perception; a reality which is in any case independent of it; a reality which constitutes the permanent mechanism of that physical universe with which our immediate empirical connection is so slight and so deceptive. That such a reality exists, though philosophers have doubted, is the unalterable faith of science; and were that faith *per impossible* to perish under the assaults of critical speculation, science, as men of science usually conceive it, would perish likewise.

If this be so, if one of the tasks of science, and more particularly of physics, is to frame a conception of the physical universe in its inner reality, then any attempt to compare the different modes in which, at different epochs of scientific development, this intellectual picture has been drawn, can not fail to suggest questions of the deepest interest. True, I am precluded from dealing with such of these questions as are purely philosophical by the character of this occasion; and with such of them as are purely scientific by my own incompetence. But some there may be sufficiently near the dividing line to induce the specialists who rule by right on either side of it, to view with forgiving eyes any trespasses into their legitimate domain which I may be tempted, during the next few minutes, to commit.

Let me then endeavor to compare the outlines of two such pictures, of which the first may be taken to represent the views prevalent towards the end of the eighteenth century; a little more than a hundred years from the publication of Newton's 'Principia,' and, roughly speaking, about midway between that epoch-making date and the present mo-

ment. I suppose that if at that period the average man of science had been asked to sketch his general conception of the physical universe, he would probably have said that it essentially consisted of various sorts of ponderable matter, scattered in different combinations through space, exhibiting most varied aspects under the influence of chemical affinity and temperature, but through every metamorphosis obedient to the laws of motion, always retaining its mass unchanged, and exercising at all distances a force of attraction on other material masses, according to a simple law. To this ponderable matter he would (in spite of Rumford) have probably added the so-called 'imponderable' heat, then often ranked among the elements; together with the two 'electrical fluids,' and the corpuscular emanations supposed to constitute light.

In the universe as thus conceived, the most important forms of action between its constituents was action at a distance; the principle of the conservation of energy was, in any general form, undreamed of; electricity and magnetism, though already the subjects of important investigation, played no great part in the whole of things; nor was a diffused ether required to complete the machinery of the universe.

Within a few months, however, of the date assigned for these deliverances of our hypothetical physicist, came an addition to this general conception of the world, destined profoundly to modify it. About a hundred years ago Young opened, or reopened, the great controversy which finally established the undulatory theory of light, and with it a belief in an interstellar medium by which undulations could be conveyed. But this discovery involved much more than the substitution of a theory of light which was consistent with the facts, for one which was not; since here was the first authentic introduction* into the scientific world picture of a new and prodigious constituent—a constituent which has altered, and is still altering, the whole balance (so to speak) of the composition. Unending space, thinly strewn with suns and satellites, made or in the making, supplied sufficient material for the mechanism of the heavens as conceived by Laplace. Unending space filled with a continuous medium was a very different affair, and gave promise of strange developments. It could not be supposed that the ether, if its reality were once admitted, existed only to convey through interstellar regions the vibrations which happen to stimulate the optic nerve of man. Invented originally to fulfil this function, to this it could never be confined. And accordingly, as every one now knows, things which, from the point of view of sense perception, are as distinct as light and radiant heat; and things to which sense per-

* The hypothesis of an ether was, of course, not new. But before Young and Fresnel it can not be said to have been established.

ception makes no response, like the electric waves of wireless telegraphy,* intrinsically differ, not in kind but in magnitude alone.

This, however, is not all, nor nearly all. If we jump over the century which separates 1804 from 1904, and attempt to give in outline the world picture as it now presents itself to some leaders of contemporary speculation, we shall find that in the interval it has been modified, not merely by such far-reaching discoveries as the atomic and molecular composition of ordinary matter, the kinetic theory of gases, and the laws of the conservation and dissipation of energy; but by the more and more important part which electricity and the ether occupy in any representation of ultimate physical reality.

Electricity was no more to the natural philosophers in the year 1700 than the hidden cause of an insignificant phenomenon.† It was known, and had long been known, that such things as amber and glass could be made to attract light objects brought into their neighborhood; yet it was about fifty years before the effects of electricity were perceived in the thunderstorm. It was about one hundred years before it was detected in the form of a current. It was about one hundred and twenty years before it was connected with magnetism; about one hundred and seventy years before it was connected with light and ethereal radiation.

But to-day there are those who regard gross matter, the matter of every-day experience, as the mere appearance of which electricity is the physical basis: who think that the elementary atom of the chemist, itself far beyond the limits of direct perception, is but a connected system of monads or subatoms which are not electrified matter, but are electricity itself; that these systems differ in the number of monads which they contain, in their arrangement, and in their motion relative to each other and to the ether; that on these differences, and on these differences alone, depend the various qualities of what have hitherto been regarded as indivisible and elementary atoms; and that while in most cases these atomic systems may maintain their equilibrium for periods which, compared with such astronomical processes as the cooling of a sun, may seem almost eternal, they are not less obedient to the law of change than the everlasting heavens themselves.

But if gross matter be a grouping of atoms, and if atoms be systems of electrical monads, what are these electrical monads? It may be that, as Professor Larmor has suggested, they are but a modification of the universal ether, a modification roughly comparable to a knot in a medium which is inextensible, incompressible and continu-

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* First known through the theoretical work of Maxwell and the experiments of Hertz.

† The modern history of electricity begins with Gilbert, but I have throughout confined my observations to the post-Newtonian period.

ous. But whether this final unification be accepted or not, it is certain that these monads can not be considered apart from the ether. It is on their interaction with the ether that their qualities depend—and without the ether an electric theory of matter is impossible.

Surely we have here a very extraordinary revolution. Two centuries ago electricity seemed but a scientific toy. It is now thought by many to constitute the reality of which matter is but the sensible expression. It is but a century ago that the title of an ether to a place among the constituents of the universe was authentically established. It seems possible now that it may be the stuff out of which that universe is wholly built. Nor are the collateral inferences associated with this view of the physical world less surprising. It used, for example, to be thought that mass was an original property of matter: neither capable of explanation nor requiring it; in its nature essentially unchangeable, suffering neither augmentation nor diminution under the stress of any forces to which it could be subjected; unalterably attached to, or identified with, each material fragment, howsoever much that fragment might vary in its appearance, its bulk, its chemical, or its physical condition.

But if the new theories be accepted these views must be revised. Mass is not only explicable, it is actually explained. So far from being an attribute of matter considered in itself, it is due, as I have said, to the relation between the electrical monads of which matter is composed and the ether in which they are bathed. So far from being unchangeable, it changes, when moving at very high speeds, with every change in its velocity.

Perhaps, however, the most impressive alteration in our picture of the universe required by these new theories is to be sought in a different direction. We have all, I suppose, been interested in the generally accepted views as to the origin and development of suns with their dependent planetary systems; and the gradual dissipation of the energy which during this process of concentration has largely taken the form of light and radiant heat. Follow out the theory to its obvious conclusions, and it becomes plain that the stars now visibly incandescent are those in mid-journey between the nebulæ from which they sprang and the frozen darkness to which they are predestined. What, then, are we to think of the invisible multitude of the heavenly bodies in which this process has been already completed? According to the ordinary view, we should suppose them to be in a state where all possibilities of internal movement were exhausted. At the temperature of interstellar space their constituent elements would be solid and inert; chemical action and molecular movement would be alike impossible, and their exhausted energy could obtain no replenishment unless they were suddenly rejuvenated by some celestial collision, or traveled into other regions warmed by newer suns.

This view must, however, be profoundly modified if we accept the electric theory of matter. We can then no longer hold that if the internal energy of a sun were as far as possible converted into heat either by its contraction under the stress of gravitation or by chemical reactions between its elements or by any other interatomic force; and that were the heat so generated to be dissipated, as in time it must be, through infinite space, its whole energy would be exhausted. On the contrary, the amount thus lost would be absolutely insignificant compared with what remained stored up within the separate atoms. The system in its corporate capacity would become bankrupt—the wealth of its individual constituents would be scarcely diminished. They would lie side by side, without movement, without chemical affinity; yet each one, howsoever inert in its external relations, the theater of violent motions, and of powerful internal forces.

Or put the same thought in another form: when the sudden appearance of some new star in the telescopic field gives notice to the astronomer that he, and, perhaps, in the whole universe, he alone, is witnessing the conflagration of a world; the tremendous forces by which this far-off tragedy is being accomplished must surely move his awe. Yet not only would the members of each separate atomic system pursue their relative course unchanged, while the atoms themselves were thus riven violently apart in flaming vapor, but the forces by which such a world is shattered are really negligible compared with those by which each atom of it is held together.

In common, therefore, with all other living things we seem to be practically concerned chiefly with the feebler forces of nature, and with energy in its least powerful manifestations. Chemical affinity and cohesion are on this theory no more than the slight residual effects of the internal electrical forces which keep the atom in being. Gravitation, though it be the shaping force which concentrates nebulæ into organized systems of suns and satellites, is trifling compared with the attractions and repulsions with which we are familiar between electrically charged bodies; while these again sink into insignificance beside the attractions and repulsions between the electric monads themselves. The irregular molecular movements which constitute heat, on which the very possibility of organic life seems absolutely to hang, and in whose transformations applied science is at present so largely concerned, can not rival the kinetic energy stored within the molecules themselves. This prodigious mechanism seems outside the range of our immediate interests. We live, so to speak, merely on its fringe. It has for us no promise of utilitarian value. It will not drive our mills; we can not harness it to our trains. Yet not less on that account does it stir the intellectual imagination. The starry heavens have, from time immemorial, moved the worship or the wonder of man-

kind. But if the dust beneath our feet be indeed compounded of innumerable systems, whose elements are ever in the most rapid motion, yet retain through uncounted ages their equilibrium unshaken, we can hardly deny that the marvels we directly see are not more worthy of admiration than those which recent discoveries have enabled us dimly to surmise.

Now whether the main outlines of the world-picture which I have just imperfectly presented to you be destined to survive, or whether in their turn they are to be obliterated by some new drawing on the scientific palimpsest, all will, I think, admit that so bold an attempt to unify physical nature excites feelings of the most acute intellectual gratification. The satisfaction it gives is almost esthetic in its intensity and quality. We feel the same sort of pleasurable shock as when from the crest of some melancholy pass we first see far below us the sudden glories of plain, river and mountain. Whether this vehement sentiment in favor of a simple universe has any theoretical justification, I will not venture to pronounce. There is no *a priori* reason that I know of for expecting that the material world should be a modification of a single medium, rather than a composite structure built out of sixty or seventy elementary substances, eternal and eternally different. Why, then, should we feel content with the first hypothesis and not with the second? Yet so it is. Men of science have always been restive under the multiplication of entities. They have eagerly noted any sign that the chemical atom was composite, and that the different chemical elements had a common origin. Nor for my part do I think such instincts should be ignored. John Mill, if I rightly remember, was contemptuous of those who saw any difficulty in accepting the doctrine of 'action at a distance.' So far as observation and experiment can tell us, bodies *do* actually influence each other at a distance; and why should they not? Why seek to go behind experience in obedience to some *a priori* sentiment for which no argument can be adduced? So reasoned Mill, and to his reasoning I have no reply. Nevertheless, we can not forget that it is to Faraday's obstinate disbelief in 'action at a distance,' that we owe some of the crucial discoveries on which both our electric industries and the electric theory of matter are ultimately founded. While at this very moment physicists, however baffled in the quest for an explanation of gravity, refuse altogether to content themselves with the belief, so satisfying to Mill, that it is a simple and inexplicable property of masses acting on each other across space.

These obscure intimations about the nature of reality deserve, I think, more attention than has yet been given to them. That they exist is certain; that they modify the indifferent impartiality of pure empiricism can hardly be denied. The common notion that he who

would search out the secrets of nature must humbly wait on experience, obedient to its slightest hint, is but partly true. This may be his ordinary attitude; but now and again it happens that observation and experiment are not treated as guides to be meekly followed, but as witnesses to be broken down in cross-examination. Their plain message is disbelieved, and the investigating judge does not pause until a confession in harmony with his preconceived ideas has, if possible, been wrung from their reluctant evidence.

This proceeding needs neither explanation nor defense in those cases where there is an apparent contradiction between the utterances of experience in different connections. Such contradictions must of course be reconciled, and science can not rest until the reconciliation is effected. The difficulty really arises when experience apparently says one thing and scientific instinct persists in saying another. Two such cases I have already mentioned; others will easily be found by those who care to seek. What is the origin of this instinct, and what its value; whether it be a mere prejudice to be brushed aside, or a clue which no wise man would disdain to follow, I can not now discuss. For other questions there are, not new, yet raised in an acute form by these most modern views of matter, on which I would ask your indulgent attention for yet a few moments.

That these new views diverge violently from those suggested by ordinary observation is plain enough. No scientific education is likely to make us, in our unreflective moments, regard the solid earth on which we stand, or the organized bodies with which our terrestrial fate is so intimately bound up, as consisting wholly of electric monads very sparsely scattered through the spaces which these fragments of matter are, by a violent metaphor, described as 'occupying.' Not less plain is it that an almost equal divergence is to be found between these new theories and that modification of the common-sense view of matter with which science has in the main been content to work.

What was this modification of common sense? It is roughly indicated by an old philosophic distinction drawn between what were called the 'primary' and the 'secondary' qualities of matter. The primary qualities, such as shape and mass, were supposed to possess an existence quite independent of the observer; and so far the theory agreed with common sense. The secondary qualities, on the other hand, such as warmth and color, were thought to have no such independent existence; being, indeed, no more than the resultants due to the action of the primary qualities on our organs of sense perception;—and here, no doubt, common sense and theory parted company.

You need not fear that I am going to drag you into the controversies with which this theory is historically connected. They have left abiding traces on more than one system of philosophy. They are not

yet solved. In the course of them the very possibility of an independent physical universe has seemed to melt away under the solvent powers of critical analysis. But with all this I am not now concerned. I do not propose to ask what proof we have that an external world exists, or how, if it does exist, we are able to obtain cognizance of it. These may be questions very proper to be asked by philosophy; but they are not proper questions to be asked by science. For, logically, they are antecedent to science, and we must reject the sceptical answers to both of them before physical science becomes possible at all. My present purpose requires me to do no more than observe that, be this theory of the primary and secondary qualities of matter good or bad, it is the one on which science has in the main proceeded. It was with matter thus conceived that Newton experimented. To it he applied his laws of motion; of it he predicated universal gravitation. Nor was the case greatly altered when science became as much preoccupied with the movements of molecules as it was with those of planets. For molecules and atoms, whatever else might be said of them, were at least pieces of matter, and, like other pieces of matter, possessed those 'primary' qualities supposed to be characteristic of all matter, whether found in large masses or in small.

But the electric theory which we have been considering carries us into a new region altogether. It does not confine itself to accounting for the secondary qualities by the primary, or the behavior of matter in bulk by the behavior of matter in atoms; it analyzes matter, whether molar or molecular, into something which is not matter at all. The atom is now no more than the relatively vast theater of operations in which minute monads perform their orderly evolutions; while the monads themselves are not regarded as units of matter, but as units of electricity; so that matter is not merely explained, but is explained away.

Now the point to which I desire to call attention is not to be sought in the great divergence between matter as thus conceived by the physicist and matter as the ordinary man supposes himself to know it, between matter as it is perceived and matter as it really is, but to the fact that the first of these two quite inconsistent views is wholly based on the second.

This is surely something of a paradox. We claim to found all our scientific opinions on experience; and the experience on which we found our theories of the physical universe is our *sense perception* of that universe. That *is* experience; and in this region of belief there is no other. Yet the conclusions which thus profess to be entirely founded upon experience are to all appearance fundamentally opposed to it; our knowledge of reality is based upon illusion; and the very conceptions we use in describing it to others, or in thinking of it our-

selves, are abstracted from anthropomorphic fancies, which science forbids us to believe and nature compels us to employ.

We here touch the fringe of a series of problems with which inductive logic ought to deal; but which that most unsatisfactory branch of philosophy has systematically ignored. This is no fault of men of science. They are occupied in the task of making discoveries, not in that of analyzing the fundamental presuppositions which the very possibility of making discoveries implies. Neither is it the fault of transcendental metaphysicians. Their speculations flourish on a different level of thought: their interest in a philosophy of nature is lukewarm; and howsoever the questions in which they are chiefly concerned be answered, it is by no means certain that the answers will leave the humbler difficulties at which I have hinted either nearer to, or further from, a solution. But though men of science and idealists stand acquitted, the same can hardly be said of empirical philosophers. So far from solving the problem, they seem scarcely to have understood that there was a problem to be solved. Led astray by a misconception to which I have already referred; believing that science was concerned only with (so-called) 'phenomena,' that it had done all that it could be asked to do if it accounted for the sequence of our individual sensations, that it was concerned only with the 'laws of nature,' and not with the inner character of physical reality; disbelieving, indeed, that any such physical reality does in truth exist;—it has never felt called upon seriously to consider what are the actual methods by which science attains its results, and how those methods are to be justified. If any one, for example, will take up Mill's logic, with its 'sequences and coexistences between phenomena,' its 'method of difference,' its 'method of agreement,' and the rest: if he will then compare the actual doctrines of science with this version of the mode in which those doctrines have been arrived at, he will soon be convinced of the exceedingly thin intellectual fare which has so often been served out to us under the imposing title of inductive theory.

There is an added emphasis given to these reflections by a train of thought which has long interested me, though I acknowledge that it never seems to have interested any one else. Observe, then, that in order of logic sense perceptions supply the premises from which we draw all our knowledge of the physical world. It is they which tell us there *is* a physical world; it is on their authority that we learn its character. But in order of causation they are effects due (in part) to the constitution of our organs of sense. What we see depends not merely on what there is to be seen, but on our eyes. What we hear depends not merely on what there is to hear, but on our ears. Now, eyes and ears, and all the mechanism of perception, have, as we know, been evolved in us and our brute progenitors by the slow operation of

natural selection. And what is true of sense perception is of course also true of the intellectual powers which enable us to erect upon the frail and narrow platform which sense perception provides, the proud fabric of the sciences.

Now natural selection only works through utility. It encourages aptitudes useful to their possessor or his species in the struggle for existence, and, for a similar reason, it is apt to discourage useless aptitudes, however interesting they may be from other points of view, because, being useless, they are probably burdensome.

But it is certain that our powers of sense perception and of calculation were fully developed ages before they were effectively employed in searching out the secrets of physical reality—for our discoveries in this field are triumphs but of yesterday. The blind forces of natural selection which so admirably simulate design when they are providing for a present need, possess no power of prevision; and could never, except by accident, have endowed mankind, while in the making, with a physiological or mental outfit adapted to the higher physical investigations. So far as natural science can tell us, every quality of sense or intellect which does not help us to fight, to eat and to bring up children, is but a by-product of the qualities which do. Our organs of sense perception were not given us for purposes of research; nor was it to aid us in meting out the heavens or dividing the atom that our powers of calculation and analysis were evolved from the rudimentary instincts of the animal.

It is presumably due to these circumstances that the beliefs of all mankind about the material surroundings in which it dwells are not only imperfect but fundamentally wrong. It may seem singular that down to, say, five years ago, our race has, without exception, lived and died in a world of illusions; and that its illusions, or those with which we are here alone concerned, have not been about things remote or abstract, things transcendental or divine, but about what men see and handle, about those 'plain matters of fact' among which common sense daily moves with its most confident step and most self-satisfied smile. Presumably, however, this is either because too direct a vision of physical reality was a hindrance, not a help, in the struggle for existence, because falsehood was more useful than truth—or else because with so imperfect a material as living tissue no better results could be attained. But if this conclusion be accepted, its consequences extend to other organs of knowledge besides those of perception. Not merely the senses, but the intellect must be judged by it; and it is hard to see why evolution, which has so lamentably failed to produce trustworthy instruments for obtaining the raw material of experience, should be credited with a larger measure of success in its provision of the physiological arrangements which condition reason in its endeavors to turn experience to account.

Considerations like these, unless I have compressed them beyond the limits of intelligibility, do undoubtedly suggest a certain inevitable incoherence in any general scheme of thought which is built out of materials provided by natural science alone. Extend the boundaries of knowledge as you may; draw how you will the picture of the universe; reduce its infinite variety to the modes of a single space-filling ether; retrace its history to the birth of existing atoms; show how under the pressure of gravitation they became concentrated into nebulæ, into suns, and all the host of heaven; how, at least in one small planet, they combined to form organic compounds; how organic compounds became living things; how living things, developing along many different lines, gave birth at last to one superior race; how from this race arose, after many ages, a learned handful, who looked round on the world which thus blindly brought them into being, and judged it, and knew it for what it was: perform (I say) all this, and though you may indeed have attained to science, in nowise will you have attained to a self-sufficing system of beliefs. One thing at least will remain, of which this long-drawn sequence of causes and effects gives no satisfying explanation; and that is knowledge itself. Natural science must ever regard knowledge as the product of irrational conditions, for in the last resort it knows no others. It must always regard knowledge as rational, or else science itself disappears. In addition, therefore, to the difficulty of extracting from experience beliefs which experience contradicts, we are confronted with the difficulty of harmonizing the pedigree of our beliefs with their title to authority. The more successful we are in explaining their origin, the more doubt we cast on their validity. The more imposing seems the scheme of what we know, the more difficult it is to discover by what ultimate criteria we claim to know it.

Here, however, we touch the frontier beyond which physical science possesses no jurisdiction. If the obscure and difficult region which lies beyond is to be surveyed and made accessible, philosophy, not science, must undertake the task. It is no business of this society. We meet here to promote the cause of knowledge in one of its great divisions; we shall not help it by confusing the limits which usefully separate one division from another. It may perhaps be thought that I have disregarded my own precept; that I have wilfully overstepped the ample bounds within which the searchers into nature carry on their labors. If it be so, I can only beg your forgiveness. My first desire has been to rouse in those, who, like myself, are no specialists in physics, the same absorbing interest which I feel in what is surely the most far-reaching speculation about the physical universe which has ever claimed experimental support; and if in so doing I have been tempted to hint my own personal opinion, that as natural science grows it leans more, not less, upon an idealistic interpretation of the universe, even those who least agree may perhaps be prepared to pardon.

THE MATHEMATICAL PHYSICS OF THE NINETEENTH CENTURY.

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THE losses sustained by mathematical science in the past twelve months have perhaps not been so numerous as in some years, but they include at least one name of world-wide import. Those of us who were students of mathematics thirty or forty years ago will recall the delight which we felt in reading the geometrical treatises of George Salmon, and the brilliant contrast which they exhibited with most of the current text-books of that time. It was from him that many of us first learned that a great mathematical theory does not consist of a series of detached propositions carefully labeled and arranged like specimens on the shelves of a museum, but that it forms an organic whole, instinct with life, and with unlimited possibilities of future development. As systematic expositions of the actual state of the science, in which enthusiasm for what is new is tempered by a due respect for what is old, and in which new and old are brought into harmonious relation with each other, these treatises stand almost unrivaled. Whether in the originals, or in the guise of translations, they are accounted as classics in every university of the world. So far as British universities are concerned, they have formed the starting point of a whole series of works conceived in a similar spirit, though naturally not always crowned by the same success. The necessity for this kind of work grows, indeed, continually; the modern fragmentary fashion of original publication and the numerous channels through which it takes place make it difficult for any one to become initiated into a new scientific theory unless he takes it up at the very beginning and follows it diligently throughout its course, backwards and forwards, over rough ground and smooth. The classical style of memoir, after the manner of Lagrange, or Poisson, or Gauss, complete in itself and deliberately composed like a work of art, is continually becoming rarer. It is therefore more and more essential that from time to time some one should come forward to sort out and arrange the accumulated material, rejecting what has proved unimportant, and welding the rest into a connected system. There is perhaps a tendency to assume that such work is of secondary importance, and can be safely left to subordinate hands. But in reality it makes severe demands on even the highest powers; and when these have been available the result has often done more for the

progress of science than the composition of a dozen monographs on isolated points. For proof one need only point to the treatises of Salmon himself, or recall (in another field) the debt which we owe to such books as the 'Treatise on Natural Philosophy' and the 'Theory of Sound,' whose authors are happily with us.

A modest but most valuable worker has passed away in the person of Professor Allman. His treatise on the history of Greek geometry, full of learning and sound mathematical perception, is written with great simplicity and an entire absence of pedantry or dogmatism. It ranks, I believe, with the best that has been done on the subject. It is to be regretted that, as an historian, he leaves so few successors among British mathematicians. We have amongst us, as a result of our system of university education, many men of trained mathematical faculty and of a scholarly turn of mind, with much of the necessary linguistic equipment, who feel, however, no special vocation for the details of recent mathematical research. Might not some of this ability be turned to a field, by no means exhausted, where the severity of mathematical truth is tempered by the human interest attaching to the lives, the vicissitudes and even the passions and the strife of its devotees, who through many errors and perplexities have contrived to keep alive and trim the sacred flame, and to hand it on burning ever clearer and brighter?

Of the various subjects which fall within the scope of this section there is no difficulty in naming that which at the present time excites the widest interest. The phenomena of radioactivity, ionization of gases, and so on, are not only startling and sensational in themselves, they have suggested most wonderful and far-reaching speculations, and, whatever be the future of these particular theories, they are bound in any case deeply to influence our views on fundamental points of chemistry and physics. No reference to this subject would, I think, be satisfactory without a word of homage to the unsurpassed patience and skill in the devising of new experimental methods to meet new and subtle conditions which it has evoked. It will be felt, as a matter of legitimate pride, by many present, that the University of Cambridge has been so conspicuously associated with this work. It would therefore have been natural and appropriate that this chair should have been occupied, this year above others, by one who could have given us a survey of the facts as they at present stand, and of their bearing, so far as can be discerned, on other and older branches of physics. Whether from the experimental or from the more theoretical and philosophical standpoint, there would have been no difficulty in finding exponents of unrivaled authority. But it has been otherwise ordered, and you and I must make the best of it. If the subject can not be further dealt with for the moment, we have the satisfaction of know-

ing that it will in due course engage the attention of the section, and that we may look forward to interesting and stimulating discussions, in which we trust the many distinguished foreign physicists who honor us by their presence will take an active part.

It is, I believe, not an unknown thing for your president to look up the records of previous meetings in search of inspiration, and possibly of an example. I have myself not had to look very far, for I found that when the British Association last met in Cambridge, in the year 1862, this section was presided over by Stokes, and moreover that the address which he gave was probably the shortest ever made on such an occasion, for it occupies only half a page of the report, and took, I should say, some three or four minutes to deliver. It would be to the advantage of the business of the meeting, and to my own great relief, if I had the courage to follow so attractive a precedent; but I fear that the tradition which has since established itself is too strong for me to break without presumption. I will turn, therefore, in the first instance, to a theme which, I think, naturally presents itself—viz., a consideration of the place occupied by Stokes in the development of mathematical physics. It is not proposed to attempt an examination or appreciation of his own individual achievements; this has lately been done by more than one hand, and in the most authoritative manner. But it is part of the greatness of the man that his work can be reviewed from more than one standpoint. What I specially wish to direct attention to on this occasion is the historical or evolutionary relation in which he stands to predecessors and followers in the above field.

The early years of Stokes's life were the closing years of a mighty generation of mathematicians and mathematical physicists. When he came to manhood, Lagrange, Laplace, Poisson, Fourier, Fresnel, Ampère had but recently passed away. Cauchy alone of this race of giants was still alive and productive. It is upon these men that we must look as the immediate intellectual ancestors of Stokes, for, although Gauss and F. Neumann were alive and flourishing, the interaction of German and English science was at that time not very great. It is noteworthy, however, that the development of the modern German school of mathematical physics, represented by Helmholtz and Kirchoff, in linear succession to Neumann, ran in many respects closely parallel to the work of Stokes and his followers.

When the foundations of analytical dynamics had been laid by Euler and d'Alembert, the first important application was naturally to the problems of gravitational astronomy; this formed, of course, the chief work of Laplace, Lagrange and others. Afterwards came the theoretical study of elasticity, conduction of heat, statical electricity, and magnetism. The investigations in elasticity were undertaken mainly in relation to physical optics, with the hope of finding a mate-

rial medium capable of conveying transverse vibrations, and of accounting also for the various phenomena of reflection, refraction and double refraction. It has often been pointed out, as characteristic of the French school referred to, that their physical speculations were largely influenced by ideas transferred from astronomy; as, for instance, in the conception of a solid body as made up of discrete particles acting on one another at a distance with forces in the lines joining them, which formed the basis of most of their work on elasticity and optics. The difficulty of carrying out these ideas in a logical manner was enormous, and the strict course of mathematical deduction had to be replaced by more or less precarious assumptions. The detailed study of the geometry of a continuous deformable medium which was instituted by Cauchy was a first step towards liberating the theory from arbitrary and unnecessary hypothesis; but it was reserved for Green, the immediate predecessor of Stokes among English mathematicians, to carry out this process completely and independently, with the help of Lagrange's general dynamical methods, which here found their first application to questions of physics outside the ordinary dynamics of rigid bodies and fluids. The modern school of English physicists, since the time of Green and Stokes, have consistently endeavored to make out, in any given class of phenomena, how much can be recognized as a manifestation of general dynamical principles, independent of the particular mechanism which may be at work. One of the most striking examples of this was the identification by Maxwell of the laws of electromagnetism with the dynamical equations of Lagrange. It would, however, be going too far to claim this tendency as the exclusive characteristic of English physicists; for example, the elastic investigations of Green and Stokes have their parallel in the independent though later work of Kirchhoff; and the beautiful theory of dynamical systems with latent motion which we owe to Lord Kelvin stands in a very similar relation to the work of Helmholtz and Hertz.

But perhaps the most important and characteristic feature in the mathematical work of the later school is its increasing relation to and association with experiment. In the days when the chief applications of mathematics were to the problems of gravitational astronomy, the mathematician might well take his materials at second hand; and in some respects the division of labor was, and still may be, of advantage. The same thing holds in a measure of the problems of ordinary dynamics, where some practical knowledge of the subject matter is within the reach of every one. But when we pass to the more recondite phenomena of physical optics, acoustics and electricity, it hardly needs the demonstrations which have involuntarily been given to show that the theoretical treatment must tend to degenerate into the pursuit of mere academic subtleties unless it is constantly vivified by direct con-

tact with reality. Stokes, at all events, with little guidance or encouragement from his immediate environment, made himself from the first practically acquainted with the subjects he treated. Generations of Cambridge students recall the enthusiasm which characterized his experimental demonstrations in optics. These appealed to us all; but some of us, I am afraid, under the influence of the academic ideas of the time, thought it a little unnecessary to show practically that the height of the lecture-room could be measured by the barometer, or to verify the calculated period of oscillation of water in a tank by actually timing the waves with the help of the image of a candle-flame reflected at the surface.

The practical character of the mathematical work of Stokes and his followers is shown especially in the constant effort to reduce the solution of a physical problem to a quantitative form. A conspicuous instance is furnished by the labor and skill which he devoted, from this point of view, to the theory of the Bessel's function, which presents itself so frequently in important questions of optics, electricity and acoustics, but is so refractory to ordinary methods of treatment. It is now generally accepted that an analytical solution of a physical question, however elegant it may be made to appear by means of a judicious notation, is not complete so long as the results are given merely in terms of functions defined by infinite series or definite integrals, and can not be exhibited in a numerical or graphical form. This view did not originate, of course, with Stokes; it is clearly indicated, for instance, in the works of Fourier and Poinsot, but no previous writer had, I think, acted upon it so consistently and thoroughly.

We have had so many striking examples of the fruitfulness of the combination of great mathematical and experimental powers that the question may well be raised, whether there is any longer a reason for maintaining in our minds a distinction between mathematical and experimental physics, or at all events whether these should be looked upon as separate provinces which may conveniently be assigned to different sets of laborers. It may be held that the highest physical research will demand in the future the possession of both kinds of faculty. We must be careful, however, how we erect barriers which would exclude a Lagrange on the one side or a Faraday on the other. There are many mansions in the palace of physical science, and work for various types of mind. A zealous, or over-zealous, mathematician might indeed make out something of a case if he were to contend that, after all, the greatest work of such men as Stokes, Kirchhoff and Maxwell was mathematical rather than experimental in its complexion. An argument which asks us to leave out of account such things as the investigation of fluorescence, the discovery of spectrum analysis and the measurement of the viscosity of gases, may seeem audacious; but a

survey of the collected works of these writers will show how much, of the very highest quality and import, would remain. However this may be, the essential point, which can not, I think, be contested, is this, that if these men had been condemned and restricted to a mere book knowledge of the subjects which they have treated with such marvelous analytical ability, the very soul of their work would have been taken away. I have ventured to dwell upon this point because, although I am myself disposed to plead for the continued recognition of mathematical physics as a fairly separate field, I feel strongly that the traditional kind of education given to our professed mathematical students does not tend to its most effectual cultivation. This education is apt to be one-sided, and too much divorced from the study of tangible things. Even the student whose tastes lie mainly in the direction of pure mathematics would profit, I think, by a wider scientific training. A long list of instances might be given to show that the most fruitful ideas in pure mathematics have been suggested by the study of physical problems. In the words of Fourier, who did so much to fulfil his own saying, "L'étude approfondie de la nature est la source la plus féconde des découvertes mathématiques. Non-seulement cette étude, en offrant aux recherches un but déterminé, a l'avantage d'exclure les questions vagues et les calculs sans issue; elle est encore un moyen assuré de former l'analyse elle-même, et d'en découvrir les éléments qu'il nous importe le plus de connaître, et que cette science doit toujours conserver: ces éléments fondamentaux sont ceux qui se reproduisent dans tous les effets naturels."

Another characteristic of the applied mathematics of the past century is that it was, on the whole, the age of linear equations. The analytical armory fashioned by Lagrange, Poisson, Fourier and others, though subject, of course, to continual improvement and development, has served the turn of a long line of successors. The predominance of linear equations, in most of the physical subjects referred to, rests on the fact that the changes are treated as infinitely small. The electric theory of light forms at present an exception; but even here the linear character of the fundamental electrical relations is itself remarkable, and possibly significant. The theory of small oscillations, in particular, runs as a thread through a great part of the literature of the period in question. It has suggested many important analytical results, and it still gives the best and simplest intuitive foundation for a whole class of theorems which are otherwise hard to comprehend in their various relations, such as Fourier's theorem, Laplace's expansion, Bessel's functions, and the like. Moreover, the interest of the subject, whether mathematical or physical, is not yet exhausted; many important problems in optics and acoustics, for example, still await solution. The general theory has in comparatively recent times re-

ceived an unexpected extension (to the case of 'latent motions') at the hands of Lord Kelvin; and Lord Rayleigh, by his continual additions to it, shows that, in his view, it is still incomplete.

When the restriction to infinitely small motions is abandoned, the problems become of course much more arduous. The whole theory, for instance, of the normal modes of vibration which is so important in acoustics, and even in music, disappears. The researches hitherto made in this direction have, moreover, encountered difficulties of a less patent character. It is conceivable that the modern analytical methods which have been developed in astronomy may have an application to these questions. It would appear that there is an opening here for the mathematician; at all events, the numerical or graphical solution of any one of the various problems that could be suggested would be of the highest interest. One problem of the kind is already classical—the theory of steep water-waves discussed by Stokes; but even here the point of view has perhaps been rather artificially restricted. The question proposed by him, the determination of the possible forms of waves of permanent type, like the problem of periodic orbits in astronomy, is very interesting mathematically, and forms a natural starting-point for investigation; but it does not exhaust what is most important for us to know in the matter. Observation may suggest the existence of such waves as a fact; but no reason has been given, so far as I know, why free water-waves should tend to assume a form consistent with permanence, or be influenced in their progress by considerations of geometrical simplicity.

I have tried to indicate the kind of continuity of subject-matter, method and spirit which runs through the work of the whole school of mathematical physicists of which Stokes may be taken as the representative. It is no less interesting, I think, to examine the points of contrast with more recent tendencies. These relate not so much to subject matter and method as to the general mental attitude towards the problems of nature. Mathematical and physical science have become markedly introspective. The investigators of the classical school, as it may perhaps be styled, were animated by a simple and vigorous faith; they sought as a matter of course for a mechanical explanation of phenomena, and had no misgivings as to the trustiness of the analytical weapons which they wielded. But now the physicist and the mathematician alike are in trouble about their souls. We have discussions on the principles of mechanics, on the foundations of geometry, on the logic of the most rudimentary arithmetical processes, as well as the more artificial operations of the calculus. These discussions are legitimate and inevitable, and have led to some results which are now widely accepted. Although they were carried on to a great extent independently, the questions involved will, I think, be found to

be ultimately very closely connected. Their common nexus is, perhaps, to be traced in the physiological ideas of which Helmholtz was the most conspicuous exponent. To many minds such discussions are repellant, in that they seem to venture on the uncertain ground of philosophy. But, as a matter of fact, the current views on these subjects have been arrived at by men who have gone to work in their own way, often in entire ignorance of what philosophers have thought on such subjects. It may be maintained chiefly, indeed, that the mathematician or the physicist, as such, has no special concern with philosophy, any more than the engineer or the geographer. Nor, although this is a matter for their own judgment, would it appear that philosophers have very much to gain by a special study of the methods of mathematical or physical reasoning, since the problems with which they are concerned are presented to them in a much less artificial form in the circumstances of ordinary life. As regards the present topic I would put the matter in this way, that between mathematics and physics on the one hand and philosophy on the other there lies an undefined borderland, and that the mathematician has been engaged in setting things in order, as he is entitled to do, on his own side of the boundary.

Adopting this point of view, it would be of interest to trace in detail the relationships of the three currents of speculation which have been referred to. At one time, indeed, I was tempted to take this as the subject of my address; but, although I still think the enterprise a possible one, I have been forced to recognize that it demands a better equipment than I can pretend to. I can only venture to put before you some of my tangled thoughts on the matter, trusting that some future occupant of this chair may be induced to take up this question and treat it in a more illuminating manner.

If we look back for a moment to the views currently entertained not so very long ago by mathematicians and physicists, we shall find, I think, that the prevalent conception of the world was that it was constructed on some sort of absolute geometrical plan, and that the changes in it proceeded according to precise laws; that, although the principles of mechanics might be imperfectly stated in our text-books, at all events such principles existed, and were ascertainable, and, when properly formulated, would possess the definiteness and precision which were held to characterize, say, the postulates of Euclid. Some writers have maintained, indeed, that the principles in question were finally laid down by Newton, and have occasionally used language which suggests that any fuller understanding of them was a mere matter of interpretation of the text. But, as Hertz has remarked, most of the great writers on dynamics betray, involuntarily, a certain *malaise* when explaining the principles, and hurry over this part of their task as quickly as is consistent with dignity. They are not really at their ease until,

having established their equations somehow, they can proceed to build securely on these. This has led some people to the view that the laws of nature are merely a system of differential equations; it may be remarked in passing that this is very much the position in which we actually stand in some of the more recent theories of electricity. As regards dynamics, when once the critical movement had set in, it was easy to show that one presentation after another was logically defective and confused; and no satisfactory standpoint was reached until it was recognized that in the classical dynamics we do not deal immediately with real bodies at all, but with certain conventional and highly idealized representations of them, which we combine according to arbitrary rules, in the hope that if these rules be judiciously framed the varying combinations will image to us what is of most interest in some of the simpler and more important phenomena. The changed point of view is often associated with the publication of Kirchhoff's lectures on mechanics in 1876, where it is laid down in the opening sentence that the problem of mechanics is to describe the motions which occur in nature completely and in the simplest manner. This statement must not be taken too literally; at all events, a fuller, and I think a clearer, account of the province and method of abstract dynamics is given in a review of the second edition of Thomson and Tait, which was one of the last things penned by Maxwell in 1879.* A 'complete' description of even the simplest natural phenomenon is an obvious impossibility; and, were it possible, it would be uninteresting as well as useless, for it would take an incalculable time to peruse. Some process of selection and idealization is inevitable if we are to gain any intelligent comprehension of events. Thus, in astronomy we replace a planet by a so-called material particle—*i. e.*, a mathematical point associated with a suitable numerical coefficient. All the properties of the body are here ignored except those of position and mass, in which alone we are at the moment interested. The whole course of physical sciences and the language in which its results are expressed have been largely determined by the fact that the ideal images of geometry were already at hand at its service. The ideal representations have the advantage that, unlike the real objects, definite and accurate statements can be made about them. Thus two lines in a geometrical figure can be pronounced to be equal or unequal, and the statement is in either case absolute. It is no doubt hard to divest oneself entirely of the notion conveyed in the Greek phrase *ἀεὶ ὁ Θεὸς γεωμετρεῖ*, that definite geometrical magnitudes and relations are at the back of phenomena. It is recognized indeed that all our measurements are necessarily to some degree uncertain, but this is usually attributed to our own limitations and those of our instruments rather than to the ultimate vagueness of the entity

* *Nature*, Vol. XX., p. 213; *Scientific Papers*, Vol. II., p. 776.

which it is sought to measure. Every one will grant, however, that the distance between two clouds, for instance, is not a definable magnitude; and the distance of the earth from the sun, and even the length of a wave of light, are in precisely the same case. The notion in question is a convenient fiction, and is a striking testimony to the ascendency which Greek mathematics have gained over our minds, but I do not think that more can be said for it. It is, at any rate, not verified by the experience of those who actually undertake physical measurements. The more refined the means employed, the more vague and elusive does the supposed magnitude become; the judgment flickers and wavers, until at last in a sort of despair *some* result is put down, not in the belief that it is exact, but with the feeling that it is the best we can make of the matter. A practical measurement is in fact a classification; we assign a magnitude to a certain category, which may be narrowly limited, but which has in any case a certain breadth.

By a frank process of idealization a logical system of abstract dynamics can doubtless be built up, on the lines sketched by Maxwell in the passage referred to. Such difficulties as remain are handed over to geometry. But we can not stop in this position; we are constrained to examine the nature and the origin of the conceptions of geometry itself. By many of us, I imagine, the first suggestion that these conceptions are to be traced to an empirical source was received with something of indignation and scorn; it was an outrage on the science which we had been led to look upon as divine. Most of us have, however, been forced at length to acquiesce in the view that geometry, like mechanics, is an applied science; that it gives us merely an ingenious and convenient symbolic representation of the relations of actual bodies; and that, whatever may be the *a priori* forms of intuition, the science as we have it could never have been developed except for the accident (if I may so term it) that we live in a world in which rigid or approximately rigid bodies are conspicuous objects. On this view the most refined geometrical demonstration can be resolved into a series of imagined experiments performed with such bodies, or rather with their conventional representations.

It is to be lamented that one of the most interesting chapters in the history of science is a blank; I mean that which would have unfolded the rise and growth of our system of ideal geometry. The finished edifice is before us, but the record of the efforts by which the various stones were fitted into their places is hopelessly lost. The few fragments of professed history which we possess were edited long after the achievement.

It is commonly reckoned that the first rude beginnings of geometry date from the Egyptians. I am inclined to think that in one sense the matter is to be placed much further back, and that the dawn of geo-

metric ideas is to be traced among the prehistoric races who carved rough but thoroughly artistic outlines of animals on their weapons. I do not know whether the matter has attracted serious speculation, but I have myself been led to wonder how men first arrived at the notion of an outline drawing. The primitive sketches referred to immediately convey to the experienced mind the idea of a reindeer or the like; but in reality the representation is purely conventional, and is expressed in a language which has to be learned. For nothing could be more unlike the actual reindeer than the few scratches drawn on the surface of a bone; and it is of course familiar to ourselves that it is only after a time, and by an insensible process of education, that very young children come to understand the meaning of an outline. Whoever he was, the man who first projected the world into two dimensions, and proceeded to fence off that part of it which was reindeer from that which was not, was certainly under the influence of a geometrical idea, and had his feet in the path which was to culminate in the refined idealizations of the Greeks. As to the manner in which these latter were developed, the only indication of tradition is that some propositions were arrived at first in a more empirical or intuitional, and afterwards in a more intellectual way. So long as points had size, lines had breadth and surfaces thickness, there could be no question of exact relations between the various elements of a figure, any more than is the case with the realities which they represent. But the Greek mind loved definiteness, and discovered that if we agree to speak of lines *as if* they had no breadth, and so on, exact statements became possible. If any one scientific invention can claim preeminence over all others, I should be inclined myself to erect a monument to the inventor of the mathematical point, as the supreme type of that process of abstraction which has been a necessary condition of scientific work from the very beginning.

It is possible, however, to uphold the importance of the part which abstract geometry has played, and must still play, in the evolution of scientific conceptions, without committing ourselves to a defense, on all points, of the traditional presentment. The consistency and completeness of the usual system of definitions, axioms and postulates have often been questioned; and quite recently a more thoroughgoing analysis of the logical elements of the subject than has ever before been attempted has been made by Hilbert. The matter is a subtle one, and a general agreement on such points is as yet hardly possible. The basis for such an agreement may perhaps ultimately be found in a more explicit recognition of the empirical source of the fundamental conceptions. This would tend, at all events, to mitigate the rigor of the demands which are sometimes made for logical perfection.

Even more important in some respects are the questions which have

arisen in connection with the applications of geometry to purposes of graphical representation. It is not necessary to dwell on the great assistance which this method has rendered in such subjects as physics and engineering. The pure mathematician, for his part, will freely testify to the influence which it has exercised in the development of most branches of analysis; for example, we owe to it all the leading ideas of the calculus. Modern analysts have discovered, however, that geometry may be a snare as well as a guide. In the mere act of drawing a curve to represent an analytical function we make unconsciously a host of assumptions which are difficult not merely to prove, but even to formulate precisely. It is now sought to establish the whole fabric of mathematical analysis on a strictly arithmetical basis. To those who were trained in an earlier school, the results so far are in appearance somewhat forbidding. If the shade of one of the great analysts of a century ago could revisit the glimpses of the moon, his feelings would, I think, be akin to those of the traveler to some medieval town, who finds the buildings he came to see obscured by scaffolding, and is told that the ancient monuments are all in process of repair. It is to be hoped that a good deal of this obstruction is only temporary, that most of the scaffolding will eventually be cleared away, and that the edifices when they reappear will not be entirely transformed, but will still retain something of their historic outlines. It would be contrary to the spirit of this address to undervalue in any way the critical examination and revision of principles; we must acknowledge that it tends ultimately to simplification, to the clearing up of issues, and the reconciliation of apparent contradictions. But it would be a misfortune if this process were to absorb too large a share of the attention of mathematicians, or were allowed to set too high a standard of logical completeness. In this particular matter of the 'arithmetization of mathematics' there is, I think, a danger in these respects. As regards the latter point, a traveler who refuses to pass over a bridge until he has personally tested the soundness of every part of it is not likely to go very far; something must be risked, even in mathematics. It is notorious that even in this realm of 'exact' thought discovery has often been in advance of strict logic, as in the theory of imaginaries, for example, and in the whole province of analysis of which Fourier's theorem is the type. And it might even be claimed that the services which geometry has rendered to other sciences have been almost as great in virtue of the questions which it implicitly begs as of those which it resolves.

I would venture, with some trepidation, to go one step further. Mathematicians love to build on as definite a foundation as possible, and from this point of view the notion of the integral number, on which (we are told) the mathematics of the future are to be based, is

very attractive. But, as an instrument for the study of nature, is it really more fundamental than the geometrical notions which it is to supersede? The accounts of primitive peoples would seem to show that, in the generality which is a necessary condition for this purpose, it is in no less degree artificial and acquired. Moreover, does not the act of enumeration, as applied to actual things, involve the very same process of selection and idealization which we have already met with in other cases? As an illustration, suppose we were to try to count the number of drops of water in a cloud. I am not thinking of the mere practical difficulties of enumeration, or even of the more pertinent fact that it is hard to say where the cloud begins or ends. Waiving these points, it is obvious that there must be transitional stages between a more or less dense group of molecules and a drop, and in the case of some of these aggregates it would only be by an arbitrary exercise of judgment that they would be assigned to one category rather than to the other. In whatever form we meet with it, the very notion of counting involves the highly artificial conception of a number of objects which for some purposes are treated as absolutely alike, whilst yet they can be distinguished.

The net result of the preceding survey is that the systems of geometry, of mechanics and even of arithmetic, on which we base our study of nature, are all contrivances of the same general kind: they consist of series of abstractions and conventions devised to represent, or rather to symbolize, what is most interesting and most accessible to us in the world of phenomena. And the progress of science consists in a great measure in the improvement, the development and the simplification of these artificial conceptions, so that their scope may be wider and the representation more complete. The best in this kind are but shadows, but we may continually do something to amend them.

As compared with the older view, the function of physical science is seen to be much more modest than was at one time supposed. We no longer hope by levers and screws to pluck out the heart of the mystery of the universe. But there are compensations. The conception of the physical world as a mechanism, constructed on a rigid mathematical plan, whose most intimate details might possibly some day be guessed, was, I think, somewhat depressing. We have been led to recognize that the formal and mathematical element is of our own introduction; that it is merely the apparatus by which we map out our knowledge, and has no more objective reality than the circles of latitude and longitude on the sun. A distinguished writer not very long ago speculated on the possibility of the scientific mine being worked out within no distant period. Recent discoveries seem to have put back this possibility indefinitely; and the tendency of modern speculation as to the nature of scientific knowledge should be to banish it altogether.

The world remains a more wonderful place than ever; we may be sure that it abounds in riches not yet dreamed of; and although we can not hope ever to explore its innermost recesses, we may be confident that it will supply tasks in abundance for the scientific mind for ages to come.

One significant result of the modern tendency is that we no longer with the same obstinacy demand a mechanical explanation of the phenomena of light and electricity, especially since it has been made clear that if one mechanical explanation is possible, there will be an infinity of others. Some minds, indeed, reveling in their new-found freedom, have attempted to disestablish ordinary or 'vulgar' matter altogether. I may refer to a certain treatise which, by some accident, does not bear its proper title of 'Æther and *no* Matter,' and to the elaborate investigations of Professor Osborne Reynolds, which present the same peculiarity, although the basis is different. Speculations of this nature have, however, been so recently and (if I may say it) so brilliantly dealt with by Professor Poynting before this section that there is little excuse for dwelling further on them now. I will only advert to the question whether, as some suggest, physical science should definitely abandon the attempt to construct mechanical theories in the older sense. The question would appear to be very similar to this, whether we should abandon the use of graphical methods in analysis. In either case we run the risk of introducing extraneous elements, possibly of a misleading character; but the gain in vividness of perception and in suggestiveness is so great that we are not likely altogether to forego it, by excess of prudence, in one case more than in the other.

We have traveled some distance from Stokes and the mathematical physics of half a century ago. May I add a few observations which might perhaps have claimed his sympathy? They are in substance anything but new, although I do not find them easy to express. We have most of us frankly adopted the empirical attitude in physical science; it has justified itself abundantly in the past, and has more and more forced itself upon us. We have given up the notion of causation, except as a convenient phrase; what were once called laws of nature are now simply rules by which we can tell more or less accurately what will be the consequences of a given state of things. We can not help asking, How is it that such rules are possible? A rule is invented in the first instance to sum up in a compact form a number of past experiences; but we apply it with little hesitation, and generally with success, to the prediction of new and sometimes strange ones. Thus the law of gravitation indicates the existence of Neptune; and Fresnel's wave-surface gives us the quite unsuspected phenomenon of double refraction. Why does nature make a point of honoring our

cheques in this manner; or, to put the matter in a more dignified form, how comes it that, in the words of Schiller,*

> 'Mit dem Genius steht die Natur im ewigen Bunde,
> Was der eine verspricht, leistet die andre gewiss'?

The question is as old as science, and the modern tendencies with which we have been occupied have only added point to it. It is plain that physical science has no answer; its policy indeed has been to retreat from a territory which it could not securely occupy. We are told in some quarters that it is vain to look for an answer anywhere. But the mind of man is not wholly given over to physical science, and will not be content forever to leave the question alone. It will persist in its obstinate questionings, and, however hopeless the attempt to unravel the mystery may be deemed, physical science, powerless to assist, has no right to condemn it.

I would like, in conclusion, to read to you a characteristic passage from that address of Stokes in 1862 which has formed the starting-point of this discourse:

"In this section, more perhaps than in any other, we have frequently to deal with subjects of a very abstract character, which in many cases can be mastered only by patient study, at leisure, of what has been written. The question may not unnaturally be asked, If investigations of this kind can best be followed by quiet study in one's own room, what is the use of bringing them forward in a sectional meeting at all? I believe that good may be done by public mention, in a meeting like the present, of even somewhat abstract investigations; but whether good is thus done, or the audience merely wearied to no purpose, depends upon the judiciousness of the person by whom the investigation is brought forward."

It might be urged that these remarks are as pertinent now as they were forty years ago, but I will leave them on their own weighty authority. I will not myself attempt to emphasize them, lest some of my hearers should be tempted to retort that the warning might well be borne in mind, not only in the ordinary proceedings of the section, but in the composition of a presidential address!

* Applied by Herschel to the discovery of Neptune.

HEREDITY AND EVOLUTION.

By WILLIAM BATESON, M.A., F.R.S.,

PRESIDENT OF THE ZOOLOGICAL SECTION OF THE BRITISH ASSOCIATION.

IN choosing a subject for this address I have availed myself of the kindly usage which permits a sectional president to divert the attention of his hearers into those lines of inquiry which he himself is accustomed to pursue. Nevertheless, in taking the facts of breeding for my theme, I am sensible that this privilege is subjected to a certain strain.

Heredity—and variation too—are matters of which no naturalist likes to admit himself entirely careless. Every one knows that, somewhere hidden among the phenomena denoted by these terms, there must be principles which, in ways untraced, are ordering the destinies of living things. Experiments in heredity have thus, as I am told, a universal fascination. All are willing to offer an outward deference to these studies. The limits of that homage, however, are soon reached, and, though all profess interest, few are impelled to make even the moderate mental effort needed to apprehend what has been already done. It is understood that heredity is an important mystery, and variation another mystery. The naturalist, the breeder, the horticulturist, the sociologist, man of science and man of practise alike, have daily occasion to make and to act on assumptions as to heredity and variation, but many seem well content that such phenomena should remain forever mysterious.

The position of these studies is unique. At once fashionable and neglected, nominally the central common ground of botany and zoology, of morphology and physiology, belonging specially to neither, this area is thinly tenanted. Now, since few have leisure for topics with which they can not suppose themselves concerned, I am aware that, when I ask you in your familiar habitations to listen to tales of a no man's land, I must forego many of those supports by which a speaker may maintain his hold on the intellectual sympathy of an audience.

Those whose pursuits have led them far from their companions can not be exempt from that differentiation which is the fate of isolated groups. The stock of common knowledge and common ideas grows smaller till the difficulty of intercommunication becomes extreme. Not only has our point of view changed, but our materials are unfamiliar, our methods of inquiry new, and even the results attained accord little with the common expectations of the day. In the progress of sciences

we are used to be led from the known to the unknown, from the half-perceived to the proven, the expectation of one year becoming the certainty of the next. It will aid appreciation of the change coming over evolutionary science if it be realized that the new knowledge of heredity and variation rather replaces than extends current ideas on those subjects.

Convention requires that a president should declare all well in his science; but I can not think it a symptom indicative of much health in our body that the task of assimilating the new knowledge has proved so difficult. An eminent foreign professor lately told me that he believed there were not half a dozen in his country conversant with what may be called Mendelism, though he added hopefully, 'I find these things interest my students more than my colleagues.' A professed biologist can not afford to ignore a new life history, the Okapi, or the other last new version of the old story; but phenomena which put new interpretations on the whole, facts witnessed continually by all who are working in these fields, he may conveniently disregard as matters of opinion. Had a discovery comparable in magnitude with that of Mendel been announced in physics or in chemistry, it would at once have been repeated and extended in every great scientific school throughout the world. We could come to a British Association audience to discuss the details of our subject—the polymorphism of extracted types, the physiological meaning of segregation, its applicability to the case of sex, the nature of non-segregable characters, and like problems with which we are now dealing—sure of finding sound and helpful criticism, nor would it be necessary on each occasion to begin with a popular presentation of the rudiments. This state of things in a progressive science has arisen, as I think, from a loss of touch with the main line of inquiry. The successes of descriptive zoology are so palpable and so attractive, that, not unnaturally, these which are the means of progress have been mistaken for the end. But now that the survey of terrestrial types by existing methods is happily approaching completion, we may hope that our science will return to its proper task, the detection of the fundamental nature of living things. I say *return,* because, in spite of that perfecting of the instruments of research characteristic of our time, and an extension of the area of scrutiny, the last generation was nearer the main quest. No one can study the history of biology without perceiving that in some essential respects the spirit of the naturalists of fifty years ago was truer in aim, and that their methods of inquiry were more direct and more fertile—so far, at least, as the problem of evolution is concerned—than those which have replaced them.

If we study the researches begun by Kölreuter and continued with great vigor till the middle of the sixties, we can not fail to see that, had the experiments he and his successors undertook been continued

on the same lines, we should by now have advanced far into the unknown. More than this: if a knowledge of what those men actually accomplished had not passed away from the memory of our generation, we should now be able to appeal to an informed public mind, having some practical acquaintance with the phenomena, and possessing sufficient experience of these matters to recognize absurdity in statement and deduction, ready to provide that healthy atmosphere of instructed criticism most friendly to the growth of truth.

Elsewhere I have noted the paradox that the appearance of the work of Darwin, which crowns the great period in the study of the phenomena of species, was the signal for a general halt. The 'Origin of Species,' the treatise which for the first time brought the problem of species fairly within the range of human intelligence, so influenced the course of scientific thought that the study of this particular phenomenon—specific difference—almost entirely ceased. That this was largely due to the simultaneous opening up of lines of research in many other directions may be granted; but in greater measure, I believe, it is to be ascribed to the substitution of a conception of species which, with all the elements of truth it contains, is yet barren and unnatural. It is not wonderful that those who held that specific difference must be a phenomenon of slowest accumulation, proceeding by steps needing generations for their perception, should turn their attention to subjects deemed more amenable to human enterprise.

The indiscriminate confounding of all divergences from type into one heterogeneous heap under the name 'Variation' effectually concealed those features of order which the phenomena severally present, creating an enduring obstacle to the progress of evolutionary science. Specific normality and distinctness being regarded as an accidental product of exigency, it was thought safe to treat departures from such normality as comparable differences: all were 'variations' alike. Let us illustrate the consequences. Princess of Wales is a large modern violet, single, with stalks a foot long or more. Marie Louise is another, with large double flowers, pale color, short stalks, peculiar scent, leaf, etc. We call these 'varieties,' and we speak of the various fixed differences between these two, and between them and wild *odorata*, as due to variation; and, again, the transient differences between the same *odorata* in poor, dry soil, or in a rich hedge-bank, we call variation, using but the one term for differences, quantitative or qualitative, permanent or transitory, in size, number of parts, chemistry, and the rest. We might as well use one term to denote the differences between a bar of silver, a stick of lunar caustic, a shilling or a teaspoon. No wonder that the ignorant tell us they can find no order in variation.

This prodigious confusion, which has spread obscurity over every part of these inquiries, is traceable to the original misconception of the nature of specific difference, as a thing imposed and not inherent.

From this, at least, the earlier experimenters were free; and the undertakings of Gärtner and his contemporaries were informed by the true conception that the properties and behavior of species were themselves specific. Free from the later fancy that but for selection the forms of animals and plants would be continuous and indeterminate, they recognized the definiteness of species and variety, and boldly set themselves to work out case by case the manifestations and consequences of that definiteness.

Over this work of minute and largely experimental analysis, rapidly growing, the new doctrine that organisms are mere conglomerates of adaptative devices descended like a numbing spell. By an easy confusion of thought, faith in the physiological definiteness of species and variety passed under the common ban which had at last exorcised the demon immutability. Henceforth no naturalist must hold communion with either, on pain of condemnation as an apostate, a danger to the dynasty of selection. From this oppression we in England, at least, are scarcely beginning to emerge. Bentham's 'Flora,' teaching very positively that the primrose, the cowslip, and the oxlip are impermanent varieties of one species, is in the hand of every beginner, while the British Museum reading-room finds it unnecessary to procure Gärtner's '*Bastarderzeugung*.'

And so this mass of specific learning has passed out of account. The evidence of the collector, the horticulturist, the breeder, the fancier, has been treated with neglect, and sometimes, I fear, with contempt. That wide field whence Darwin drew his wonderful store of facts has been some forty years untouched. Speak to professional zoologists of any breeder's matter, and how many will not intimate to you politely that fanciers are unscientific persons, and their concerns beneath notice? For the concrete in evolution we are offered the abstract. Our philosophers debate with great fluency whether between imaginary races sterility could grow up by an imaginary selection; whether selection working upon hypothetical materials could produce sexual differentiation; how under a system of natural selection bodily symmetry may have been impressed on formless protoplasm—that monstrous figment of the mind, fit starting-point for such discussions. But by a physiological irony enthusiasm for these topics is sometimes fully correlated with indifference even to the classical illustrations; and for many whose minds are attracted by the abstract problem of interracial sterility there are few who can name for certain ten cases in which it has been already observed.

And yet in the natural world, in the collecting-box, the seed-bed, the poultry-yard, the places where variation, heredity, selection, may be seen in operation and their properties tested, answers to these questions meet us at every turn—fragmentary answers, it is true, but each direct to the point. For if any one will stoop to examine nature in

those humble places, will do a few days' weeding, prick out some rows of cabbages, feed up a few score of any variable larva, he will not wait long before he learns the truth about variation. If he go further and breed two or three generations of almost any controllable form, he will obtain immediately facts as to the course of heredity which obviate the need for much laborious imagining. If strictly trained, with faith in the omnipotence of selection, he will not proceed far before he encounters disquieting facts. Upon whatever character the attention be fixed, whether size, number, form of the whole or of the parts, proportion, distribution of differentiation, sexual characters, fertility, precocity or lateness, color, susceptibility to cold or to disease—in short, all the kinds of characters which we think of as best exemplifying specific difference, we are certain to find illustrations of the occurrence of departures from normality, presenting exactly the same definiteness elsewhere characteristic of normality itself. Again and again the circumstances of their occurrence render it impossible to suppose that these striking differences are the product of continued selection, or, indeed, that they represent the results of a gradual transformation of any kind. Whenever by any collocation of favoring circumstance such definite novelties possess a superior viability, supplanting their 'normal' relatives, it is obvious that new types will be created.

The earliest statement of this simple inference is, I believe, that of Marchant,* who in 1719, commenting on certain plants of *Mercurialis* with laciniated and hair-like leaves, which for a time established themselves in his garden, suggested that species may arise in like manner. Though the same conclusion has appeared inevitable to many, including authorities of very diverse experience, such as Huxley, Virchow, F. Galton, it has been strenuously resisted by the bulk of scientific opinion, especially in England. Lately, however, the belief in mutation, as De Vries has taught us to call it, has made notable progress,† owing to the publication of his splendid collection of observations and experiments, which must surely carry conviction of the reality and abundance of mutation to the minds of all whose judgments can be affected by evidence.

That the dread test of natural selection must be passed by every aspirant to existence, however brief, is a truism which needs no special

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* Marchant, *Mém. Ac. roy. des sci.* for 1719; 1721, p. 59, Pls. 6–7. I owe this reference to Coutagne, *L'hérédité chez les vers à soie* (*Bull. sci. Fr. Belg.*, 1902).

† This progress threatens to be rapid indeed. Since these lines were written Professor Hubrecht, in an admirable exposition (Pop. Sci. Monthly, July, 1904) of De Vries's 'Mutations-theorie,' has even blamed me for having ten years ago attached *any* importance to continuous variation. Nevertheless, when the unit of segregation is small, something mistakably like continuous evolution must surely exist. (Cp. Johannsen, 'Ueb. Erblichkeit in Populationen und in reinen Linien,' 1903.)

proof. Those who find satisfaction in demonstrations of the obvious may amply indulge themselves by starting various sorts of some annual, say French poppy, in a garden, letting them run to seed, and noticing in a few years how many of the finer sorts are represented; or by sowing an equal number of seeds taken from several varieties of carnation, lettuce or auricula, and seeing in what proportions the fine kinds survive in competition with the common.

Selection is a true phenomenon; but its function is to *select,* not to create. Many a white-edged poppy may have germinated and perished before Mr. Wilks saved the individual which in a few generations gave rise to the shirleys. Many a black *Amphidasys betularia* may have emerged before, some sixty years ago, in the urban conditions of Manchester the black var. *doubledayaria* found its chance, soon practically superseding the type in its place of origin, extending itself over England, and reappearing even in Belgium and Germany.

Darwin gave us sound teaching when he compared man's selective operations with those of nature. Yet how many who are ready to expound nature's methods have been at the pains to see how man really proceeds? To the domesticated form our fashions are what environmental exigency is to the wild. For years the conventional Chinese primrose threw sporadic plants of the loose-growing *stellata* variety, promptly extirpated because repugnant to mid-Victorian primness. But when taste, as we say, revived, the graceful star primula was saved by Messrs. Sutton, and a stock raised which is now of the highest fashion. I dare assert that few botanists meeting *P. stellata* in nature would hesitate to declare it a good species. This and the shirleys precisely illustrate the procedure of the raiser of novelties. His operations start from a definite beginning. As in the case of *P. stellata,* he may notice a mutational form thrown off perfect from the start, or, as in the shirleys, what catches his attention may be the first indication of that flaw which if allowed to extend will split the type into a host of new varieties each with its own peculiarities and physiological constitution.

Let any one who doubts this try what he can do by selection without such a definite beginning. Let him try from a pure strain of black and white rats to raise a white one by breeding from the whitest, or a black one by choosing the blackest. Let him try to raise a dwarf ('Cupid') sweet pea from a tall race by choosing the shortest, or a crested fowl by choosing the birds with most feathers on their heads. To formulate such suggestions is to expose their foolishness.

The creature is beheld to be very good after, not before its creation. Our domesticated races are sometimes represented as so many incarnations of the breeder's prophetic fancy. But except in recombinations of preexisting characters—now a comprehensible process—and in such intensifications and such finishing touches as involve variations

which analogy makes probable, the part played by prophecy is small. Variation leads; the breeder follows. The breeder's method is to notice a desirable novelty, and to work up a stock of it, picking up other novelties in his course—for these genetic disturbances often spread—and we may rest assured the method of nature is not very different.

The popular belief that evolution, whether natural or artificial, is effected by mass-selection of impalpable differences arises from many errors which are all phases of one—imperfect analysis—though the source of the error differs with the circumstances of its exponent. When the scientific advocate professes that he has statistical proofs of the continuity of variation, he is usually availing himself of that comprehensive use of the term variation to which I have referred. Statistical indications of such continuity are commonly derived from the study, not of nascent varieties, but of the fluctuations to which all normal populations are subject. Truly varying material needs care in its collection, and if found is often sporadic or in some other way unsuitable for statistical treatment. Sometimes it happens that the two phenomena are studied together in inextricable entanglement, and the resulting impression is a blur.

But when a practical man, describing his own experience, declares that the creation of his new breed has been a very long affair, the scientist, feeling that he has found a favorable witness, puts forward this testimony as conclusive. But on cross-examination it appears that the immense period deposed to seldom goes back beyond the time of the witness's grandfather, covering, say, seventy years; more often ten, or eight, or even five years will be found to have accomplished most of the business. Next, in this period—which, if we take it at seventy years, is a mere point of time compared with the epochs of which the selectionist discourses—a momentous transformation has often been effected, not in one character but many. Good characters have been added, it may be, of form, fertility, precocity, color and other physiological attributes, undesirable qualities have been eliminated, and all sorts of defects 'rogued' out. On analysis these operations can be proved to depend on a dozen discontinuities. Be it, moreover, remembered that within this period, besides *producing* his mutational character and combining it with other characters (or it may be groups of characters), the breeder has been working up a *stock*, reproducing in quantity that quality which first caught his attention, thus converting, if you will, a phenomenon of individuals into a phenomenon of a mass, to the future mystification of the careless.

Operating among such phenomena the gross statistical method is a misleading instrument; and, applied to these intricate discriminations, the imposing correlation table into which the biometrical Procrustes fits his arrays of unanalyzed data is still no substitute for the common sieve of a trained judgment. For nothing but minute analysis of the

facts by an observer thoroughly conversant with the particular plant or animal, its habits and properties, checked by the test of crucial experiment, can disentangle the truth.

To prove the reality of selection as a factor in evolution is, as I have said, a work of supererogation. With more profit may experiments be employed in defining the *limits* of what selection can accomplish. For whenever we can advance no further by selection, we strike that hard outline fixed by the natural properties of organisms. We come upon these limits in various unexpected places, and to the naturalist ignorant of breeding nothing can be more surprising or instructive.

Whatever be the mode of origin of new types, no theoretical evolutionist doubts that selection will enable him to fix his character when obtained. Let him put his faith into practise. Let him set about breeding canaries to win in the class for Clear Yellow Norwich at the Crystal Palace Show. Being a selectionist, his plan will be to pick up winning yellow cocks and hens at shows and breed them together. The results will be disappointing. Not getting what he wants, he may buy still better clear yellows and work them in, and so on till his funds are exhausted, but he will pretty certainly breed no winner, be he never so skilful. For no selection of winning yellows will make them into a breed. They must be formed afresh by various combinations of colors appropriately crossed and worked up. Though breeders differ as to the system of combinations to be followed, all would agree that selection of birds representing the winning type was a sure way to fail. The same is true for nearly all canary colors except in lizards, and, I believe, for some pigeon and poultry colors also.

Let this scientific fancier now go to the Palace Poultry Show and buy the winning brown leghorn cock and hen, breed from them, and send up the result of such a mating year after year. His chance of a winner is not quite, but almost *nil.* For in its wisdom the fancy has chosen one type for the cock and another for the hen. They belong to distinct strains. The hen corresponding to the winning cock is too bright, and the cock corresponding to the winning hen is too dull for the judge's taste. The same is the case in nearly every breed where the sex-colors differ markedly. Rarely winners of both sexes have come in one strain—a phenomenon I can not now discuss—but the contrary is the rule. Does any one suppose that this system of 'double mating' would be followed, with all the cost and trouble it involves, if selection could compress the two strains into one? Yet current theory makes demands on selection to which this is nothing.

The tyro has confidence in the power of selection to fix type, but he never stops to consider what fixation precisely means. Yet a simple experiment will tell him. He may go to a great show and claim the

best pair of Andalusian fowls for any number of guineas. When he breeds from them he finds, to his disgust, that only about half their chickens, or slightly more, come blue at all, the rest being blacks or splashed whites. Indignantly, perhaps, he will complain to the vendor that he has been supplied with no selected breed, but worthless mongrels. In reply he may learn that beyond a doubt his birds come from blues only in the direct line for an indefinite number of generations, and that to throw blacks and splashed whites is the inalienable property of blue Andalusians. But now let him breed from his 'wasters,' and he will find that the extracted blacks are *pure* and give blacks only, that the splashed whites similarly give only whites or splashed whites —but if the two sorts of 'wasters' are crossed together *blues only* will result. *Selection* will never make the blues breed true; nor can this ever come to pass unless a blue be found whose germ-cells are bearers of the blue character—which may or may not be possible. If the selectionist reflect on this experience he will be led straight to the center of our problem. There will fall, as it were, scales from his eyes, and in a flash he will see the true meaning of fixation of type, variability and mutation, vaporous mysteries no more.

Owing to the unhappy subdivisions of our studies, such phenomena as these—constant companions of the breeder—come seldom within the purview of modern science, which, forced for a moment to contemplate them, expresses astonishment and relapses into indolent scepticism. It is in the hope that a little may be done to draw research back into these forgotten paths that I avail myself of this great opportunity of speaking to my colleagues with somewhat wider range of topic than is possible within the limits of a scientific paper. For I am convinced that the investigation of heredity by experimental methods offers the sole chance of progress with the fundamental problems of evolution.

In saying this I mean no disrespect to that study of the physiology of reproduction by histological means, which, largely through the stimulus of Weismann's speculations, has of late made such extraordinary advances. It needs no penetration to see that, by an exact knowledge of the processes of maturation and fertilization, a vigorous stock is being reared, upon which some day the experience of the breeder will be firmly grafted, to our mutual profit. We, who are engaged in experimental breeding, are watching with keenest interest the researches of Strasburger, Boveri, Wilson, Farmer and their many fellow-workers and associates in this difficult field, sure that in the near future we shall be operating in common. We know already that the experience of the breeder is in no way opposed to the facts of the histologist; but the point at which we shall unite will be found when it is possible to trace in the maturing germ an indication of some character afterwards recognizable in the resulting organism. Till then, in order to pursue directly the course of heredity and variation, it is evident that we must

fall back on those tangible manifestations which are to be studied only by field observation and experimental breeding.

The breeding-pen is to us what the test-tube is to the chemist—an instrument whereby we examine the nature of our organisms and determine empirically what for brevity I may call their genetic properties. As unorganized substances have their definite properties, so have the several species and varieties which form the materials of our experiments. Every attempt to determine these definite properties contributes immediately to the solution of that problem of problems, the physical constitution of a living organism. In those morphological studies which I suppose most of us have in our time pursued, we sought inspiration from the belief that in the examination of present normalities we were tracing the past, the phylogenetic order of our types, the history—as we conceived—of evolution. In the work which I am now pressing upon your notice we may claim to be dealing not only with the present and the past, but with the future also.

On such an occasion as this it is impossible to present to you in detail the experiments—some exceedingly complex—already made in response to this newer inspiration. I must speak of results, not of methods. At a later meeting, moreover, there will be opportunities of exhibiting practically to those interested some of the more palpable illustrations. It is also impossible to-day to make use of the symbolic demonstrations by which the lines of analysis must be represented. The time can not be far distant when ordinary Mendelian formulæ will be mere *as in præsenti* to a biological audience. Nearly five years have passed since this extraordinary rediscovery was made known to the scientific world by the practically simultaneous papers of De Vries, Correns and Tschermak, not to speak of thirty-five years of neglect endured before. Yet a phenomenon comparable in significance with any that biological science has revealed remains the intellectual possession of specialists. We still speak sometimes of Mendel's hypothesis or theory, but in truth the terms have no strict application. It is no theory that water is made up of hydrogen and oxygen, though we can not watch the atoms unite, and it is no theory that the blue Andalusian fowl I produce was made by the meeting of germ-cells bearing respectively black and a peculiar white. Both are incontrovertible facts deduced from observation. The two facts have this in common also, that their perception gives us a glimpse into that hidden order out of which the seeming disorder of our world is built. If I refer to Mendelian 'theory,' therefore, in the words with which Bacon introduced his Great Instauration, 'I entreat men to believe that it is not an opinion to be held, but a work to be done; and to be well assured that I am laboring to lay the foundation, not of any sect or doctrine, but of human utility and power.'

ON THE PERCEPTION OF THE FORCE OF GRAVITY BY PLANTS.

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PRESIDENT OF THE BOTANICAL SECTION OF THE BRITISH ASSOCIATION.

WHEN I had the honor of addressing this association at Cardiff as president of the mother section from which ours has sprung by fission—I spoke of the mechanism of the curvatures commonly known as tropisms. To-day I propose to summarize the evidence—still far from complete—which may help us to form a conception of the mechanism of the stimulus which calls forth one of these movements—namely, geotropism. I have said that the evidence is incomplete, and perhaps I owe you an apology for devoting the time of this section to an unsolved problem. But the making of theories is the romance of research; and I may say, in the words of Diana of the Crossways, who indeed spoke of romance, 'The young who avoid that region escape the title of fool at the cost of a celestial crown.' I am prepared for the risk in the hope that in not avoiding the region of hypothesis I shall at least be able to interest my hearers.

The modern idea of the behavior of plants to their environment has been the growth of the last twenty-five years; though, as Pfeffer has shown, it was clearly stated in 1824 by Dutrochet, who conceived the movements of plants to be 'spontaneous'—*i. e.*, to be executed at the suggestion of changes in the environment, not as the direct and necessary result of such changes. I have been in the habit of expressing the same thought in other words, using the idea of a guide or signal, by the interpretation of which plants are able to make their way successfully through the difficulties of their surroundings. In the existence of the force of gravity we have one of the most striking features of the environment, and in the sensitiveness to gravity which exists in plants we have one of the most widespread cases of a plant reading a signal and directing its growth in relation to its perception. I use the word perception not of course to imply consciousness, but as a convenient form of expression for a form of irritability. It is as though the plant discovered from its sensitiveness to gravity the line of the earth's radius, and then chose a line of growth bearing a certain relation to the vertical line so discovered, either parallel to it or across it at various angles. This, the reaction or reply to the stimulus, is, in my judgment, an adaptive act forced on the species by the struggle for life. This point of view, which, as I regret to think, is not very fash-

ionable, need not trouble us. We are not concerned with why the plant grows up into the air or down into the ground; we are only concerned with the question of how the plant perceives the existence of gravitation. Or, in other words, taking the reaction for granted, what is the nature of the stimulus? If a plant is beaten down by wind or by other causes into a horizontal position, what stimulative change is wrought in the body of the plant by this new posture?

It is conceivable in the case of a stem supported by one end and projecting freely in the air that the unaccustomed state of strain might act as a signal. The tissues on one side (the upper) are stretched, and they are compressed below; this might guide the plant; it might, in fact, have evolved the habit of rapid growth in the compressed side. This is only given as an illustration, for we know that the stimulus does not arise in this way, since such a plant, supported throughout its length, and, therefore, suffering no strain, is geotropically stimulated. The illustration is so far valuable, as it postulates a stimulus produced by weight, and we know from Knight's centrifugal experiment that weight is the governing factor in the conditions. Since we can not believe that the stimulus arises from the strain as affecting the geotropic organ as a whole, we must seek for weight-effects in the individual cell of which the plant is built. We must, in fact, seek for weight-effects on the ectoplasm of those cells which are sensitive to the stimulus of gravity.

If we imagine a plant consisting of a single apogeotropic cell we shall see that the hydrostatic pressure of the cell-contents might serve as a signal.

As long as the cell is vertical the hydrostatic pressure of the cell-sap upon the ectoplasm at C (Fig. 1) is equal to that at D. But the pressure on the basal wall, B, differs from that at A (the apical wall)

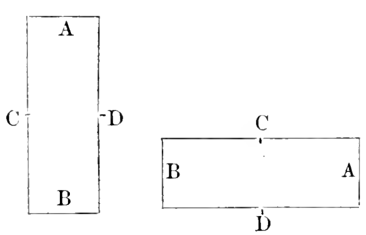

Fig. 1.

by the weight of the column AB. If the plant be forced into the horizontal, the pressure at A and B becomes the same, while the pressure at C no longer equals that at D, but differs by the weight of the column CD. Here undoubtedly is a possible means by which the plant could perceive that it was no longer vertical, and would have the means of

distinguishing up from down. So that if it were an apogeotropic plant it would need to develop the instinct of relatively accelerated growth on the side *D,* on which the pressure is greatest.

What is here roughly sketched is the groundwork of the theory of *graviperception* suggested by Pfeffer and supported by Czapek, which I shall speak of as the radial pressure theory, and to which I shall return later.

It is obvious that there is another consideration to be taken into account, namely, that cells do not contain cell-sap only, but various bodies—nucleus, chloroplasts, crystals, etc.—and that these bodies, differing in specific gravity from the cell-sap, will exert pressure on the physically lower or physically higher cell-walls according as they are heavier or lighter than the cell-sap. Here we have the possibility of a sense-organ for verticality. As long as the stem is vertical and the apex upwards the heavy bodies rest on the basal wall, and the plant is not stimulated to curvature; but if placed horizontally, so that the heavy bodies rest on the lateral cell-walls, which are now horizontal, the plant *is* stimulated to curve. This is known as the *statolith theory.*

It seems to me quite certain that the stimulus must originate either in the weight of solid particles or in the weight of the fluid in the cells, or by both these means together. And for this reason. Take the statolith theory first. There undoubtedly are heavy bodies in cells; for instance, certain loose, movable starch-grains. Now, either these starch-grains are specialized to serve the purpose of graviperception or they are not. If they are so specialized, *cadit quæstio;* if they are not, there still remains this interesting point of view; the starch-grains fall to the lower end of the cells in which they occur; therefore, shortly before every geotropic curvature which has taken place since movable starch-grains came into existence, there has been a striking change in the position of these heavy cell contents. Now, if we think of the evolution of geotropism as an adaptive manner of growth we must conceive plants growing vertically upwards and succeeding in life, others not so behaving, and consequently failing. There will be a severe struggle tending to pick out those plants which associated certain curvatures with certain preceding changes, and therefore it seems to me that, if movable starch-grains were originally in no way specialized as part of the machinery of graviperception, they would necessarily become an integral part of that machinery, since the act of geotropism would become adherent to or associated with the falling of the starch-grains.

This argument must in fairness be applied to any other physical conditions which constantly precede geotropic curvature; it is, therefore, not an argument in favor of the statolith theory alone, but equally

for the pressure theory, and can not help us to decide between the two points of view.

Are there any general considerations which can help us to decide for or against the statolith theory? I think there are—namely, (1) analogy with the graviperceptive organs of animals; (2) the specialization and distribution of the falling bodies in plants.

Berthold (to whom the credit is due of having first suggested that Dehnecke's falling starch-grains might function as originators of geotropic reaction) is perhaps somewhat bold in saying that 'the primary effect of gravity' as regards stimulation must depend on the passive sinking of the heavier parts. Noll, too, says that Knight's experiment depends on weight, and not the weight of complete parts of the plant-body, but of weight within the irritable structure. I can not see that these downright statements are justified on direct evidence, and I accordingly lay some stress on the support of zoological evidence. It has been conclusively proved by Kreidl's beautiful experiment that in the Crustacean *Palæmon* the sense of verticality depends on the pressure of heavy bodies on the inside of cavities now known as statocysts, and formerly believed to be organs of hearing. The point of the experiment is that when the normal particles are replaced by fragments of iron the *Palæmon* reacts towards the attraction of a magnet precisely as it formerly reached towards gravity.

It is unfortunate that Noll's arguments in favor of the existence of a similar mechanism in plants were not at once followed by the demonstration of those easily visible falling bodies, which, in imitation more flattering than accurate, are called *statoliths,* after the bodies in the statocysts of animals. Personally I was convinced by Kreidl, as quoted by Noll, that here was the key to graviperception in plants. But it was not until the simultaneous appearance of Haberlandt's and Němec's papers that my belief became active, and this, I think, was the case with others. The whole incident is an instance of what my father says somewhere about the difficulty of analyzing the act of belief. I find it impossible to help believing in the statolith theory, though I own to not being able to give a good account of the faith that is in me. It is a fair question whether the analogy drawn from animals gives any support to the theory for plants. The study of sense-organs in plants dates, I think, in its modern development, at least, from my father's work on root-tips, and on the light-perceiving apices of certain seedlings. And the work on the subject is all part of the wave of investigation into adaptations which followed the publication of the 'Origin of Species.' It is very appropriate that one of the two authors to whom we owe the practical working out of the statolith theory should also be one of the greatest living authorities on adaptation in plants. Haberlandt's work on sense-organs, especially on the apparatus for the

reception of contact stimuli, is applicable to our present case, since he has shown that the organs for intensifying the effect of contact are similar in the two kingdoms. No one supposes that the whisker of a cat and the sensitive papilla of a plant are phylogenetically connected. It is a case of what Ray Lankester called homoplastic resemblance. Necessity is the mother of invention, but invention is not infinitely varied, and the same need has led to similar apparatus in beings which have little more in common than that both are living organisms.

But, whether we are or are not affected in our belief by the general argument from analogy, we can not neglect the important fact that Kreidl proves the possibility of gravisensitiveness depending on the possession of statoliths. We must add to this a very important consideration—namely, that we know from Němec's work that an alteration in the position of the statoliths does stimulate the *statocyte*. Such, at least, is, to my mind, the only conclusion to be drawn from the remarkable accumulation of protoplasm which occurs, for instance, on the basal wall of a normally vertical cell when that wall is cleared of statoliths by temporary horizontality. The fact that a visible disturbance in the plasmic contents of the statocyte follows the disturbance of the starch-grains seems to me a valuable contribution to the evidence.

There is one other set of facts of sufficiently general interest to find a place in this section. I mean Haberlandt's result, also independently arrived at by myself, that when a plant is placed horizontally and rapidly shaken up and down in a vertical plane the gravistimulus is increased. This is readily comprehensible on the statolith theory, since we can imagine the starch-grains would give a greater stimulus if made to vibrate on one of the lateral walls, or if forced into the protoplasm, as Haberlandt supposes. I do not see that the difference in the pressure of the cell-sap on the upper and lower walls (*i. e.*, the lateral walls morphologically considered) would be increased. It would, I imagine, be rendered uneven; but the average difference would remain the same. But in the case of the starch-grains an obvious new feature is introduced by exchanging a stationary condition for one of movement. And though I speak with hesitation on such a point, I am inclined to see in Haberlandt's and my own experiments a means of distinguishing between the pressure and statolith theories. Noll, however, considers that the shaking method is not essentially different from that of Knight's experiment, and adds that the result might have been foreseen.

THE ETHNOLOGICAL WORK OF LANE FOX.

BY HENRY BALFOUR, M.A.,

PRESIDENT OF THE ANTHROPOLOGICAL SECTION OF THE BRITISH ASSOCIATION.

THE earth, as we know, is peopled with races of the most heterogeneous description, races in all stages of culture. Colonel Lane Fox argued that, making due allowance for possible instances of degradation from a higher condition, this heterogeneity could readily be explained by assuming that, while the progress of some races has received relatively little check, the culture development of other races has been retarded to a greater or less extent, and that we may see represented conditions of at least partially arrested development. In other words, he considered that in the various manifestations of culture among the less civilized peoples were to be seen more or less direct *survivals* from the earlier stages or strata of human evolution; vestiges of ancient conditions which have fallen out at different points and have been left behind in the general march of progress.

Taken together, the various living races of man seem almost to form a kind of living genealogical tree, as it were, and it is as an epiphyte upon this tree that the comparative ethnologist largely thrives; while to the archeologist it may also prove a tree of knowledge the fruit of which may be eaten with benefit rather than risk.

This certainly seems to be a legitimate assumption in a general way; but there are numerous factors which should be borne in mind when we endeavor to elucidate the past by means of the present. If the various gradations of culture exhibited by the condition of living races—the savage, semi-civilized, or barbaric, and the civilized races—could be regarded as accurately typifying the successive stages through which the higher forms of culture have been evolved in the course of the ages; if, in fact, the different modern races of mankind might be accepted as so many sections of the human race whose intellectual development has been arrested or retarded at various definite stages in the general progression, then we should have, to all intents and purposes, our genealogical tree in a very perfect state, and by its means we could reconstruct the past and study with ease the steady growth of culture and handicrafts from the earliest simple germs, reflecting the mental condition of primeval man up to the highest manifestations of the most cultured races.

These ideal conditions are, however, far from being realized. Intellectual progress has not advanced along a single line, but, in its

development, it has branched off in various directions, in accordance with varying environment; and the tracing of lines of connection between different forms of culture, as is the case with the physical variations, is a matter of intricate complexity. Migrations with the attendant climatic changes, change of food, and, in fact, of general environment, to say nothing of the crossing of different stocks, transmission of ideas from one people to another, and other factors, all tend to increase the tangle.

Although in certain instances savage tribes or races show obvious signs of having *degenerated* to some extent from conditions of a higher culturedom, this can not be regarded as the general rule, and we must always bear in mind the seemingly paradoxical truth that degradation in the culture of the lower races is often, if not usually, the direct result of contact with peoples in a far higher state of civilization.

There can, I think, be little doubt that Colonel Lane Fox was well justified in urging the view that most savage races are in large measure strictly *primitive,* survivals from early conditions, the development of their ideas having from various causes remained practically stationary during a very considerable period of time. In the lower, though not degenerate, races signs of this are not wanting, and while few, possibly none, can be said to be absolutely in a condition of arrested development, their normal progress is at a slow, in most cases at a *very* slow, rate.

Perhaps the best example of a truly primitive race existing in recent times, of which we have any knowledge, was afforded by the native inhabitants of Tasmania. This race was still existing fifty years ago, and a few pure-blooded survivors remained as late as about the year 1870, when the race became extinct, the benign civilizing influence of enlightened Europeans having wiped this extremely interesting people off the face of the earth. The Australians, whom Colonel Lane Fox referred to as being 'the lowest amongst the existing races of the world of whom we have any accurate knowledge,' are very far in advance of the Tasmanians, whose lowly state of culture conformed thoroughly with the characteristics of a truly primitive race, a survival not only from the stone age in general, but from almost the earliest beginnings of the stone age. The difference between the culture of the Tasmanians and that of the Australians was far greater than that which exists between man of the 'river drift' period and his Neolithic successors. The objects of every-day use were but slight modifications of forms suggested by nature, involving the exercise of merely the simplest mental processes. The stone implements were of the rudest manufacture, far inferior in workmanship to those made by Paleolithic man; they were never ground or polished, never even fitted with handles, but were merely grasped in the hand. The *varieties* of imple-

ments were very *few in number,* each, no doubt, serving a number of purposes, the function varying with the requirements of the moment. They had no bows or other appliances for accelerating the flight of missiles, no pottery, no permanent dwellings; nor is there any evidence of a previous knowledge of such products of higher culture. They seem to represent a race which was isolated very early from contact with higher races; in fact, before they had developed more than the merest rudiments of culture—a race continuing to live under the most primitive conditions, from which they were never destined to emerge.

Between the Tasmanians, representing in their very low culture the one extreme, and the most civilized peoples at the other extreme, lie races exhibiting in a general way intermediate conditions of advancement or retardation. If we are justified, as I think we are, in regarding the various grades of culture observable among the more lowly of the still existing races of man as representing to a considerable extent those vanished cultures which in their succession formed the different stages by which civilization emerged gradually from a low state, it surely becomes a very important duty for us to study with energy these living illustrations of early human history in order that the archeological record may be supplemented and rendered more complete. The material for this study is vanishing so fast with the spread of civilization that opportunities lost now will never be regained, and already even it is practically impossible to find native tribes which are wholly uncontaminated with the products, good or bad, of higher cultures.

The arts of living races help to elucidate what is obscure in those of prehistoric times by the process of reasoning from the known to the unknown. It is the work of the zoologist which enables the paleontologist to reconstruct the forms of extinct animals from such fragmentary remains as have been preserved, and it is largely from the results of a comparative study of living forms and their habitats that he is able, in his descriptions, to equip the reconstructed types of a past fauna with environments suited to their structure, and to render more complete the picture of their mode of life.

In like manner, the work of the ethnologist can throw light upon the researches of the archeologist; through it broken sequences may be repaired, at least suggestively, and the interpretation of the true nature and use of objects of antiquity may frequently be rendered more sure. Colonel Lane Fox strongly advocated the application of the reasoning methods of biology to the study of the origin, phylogeny and etionomics of the arts of mankind, and his own collection demonstrated that the products of human intelligence can conveniently be classified into families, genera, species and varieties, and *must* be so grouped if their affinities and development are to be investigated.

It must not be supposed—although some people, through misap-

prehension of his methods, jumped at this erroneous conclusion—that he was unaware of the danger of possibly mistaking mere accidental resemblances for morphological affinities, and that he assumed that *because* two objects, perhaps from widely separated regions, appeared more or less identical in form, and possibly in use, they were necessarily to be considered as members of one phylogenetic group. On the contrary, in the grouping of his specimens according to their form and function, he was anxious to assist as far as possible in throwing light upon the question of the monogenesis or polygenesis of certain arts and appliances, and to discover whether they are exotic or indigenous in the regions in which they are now found, and, in fact, to distinguish between mere analogies and true homologies. If we accept the theory of the monogenesis of the human race, as most of us undoubtedly do, we must be prepared to admit that there prevails a condition of unity in the tendencies of the human mind to respond in a similar manner to similar stimuli. Like conditions beget like results; and thus instances of independent invention of similar objects are liable to arise. For this very reason, however, the arts and customs belonging to even widely separated peoples may, though apparently unrelated, help to elucidate some of the points in each other's history which remain obscure through lack of the evidence required to establish *local* continuity.

I think, moreover, that it will generally be allowed that cases of 'independent invention' of similar forms should be considered to have established their claim to be regarded as such only after exhaustive inquiry has been made into the possibilities of the resemblances being due to actual relationship. There is the alternative method of assuming that, because two like objects are widely separated geographically, and because a line of connection is not immediately obvious, therefore the resemblance existing between them is fortuitous, or merely the natural result of similar forms having been produced to meet similar needs. Premature conclusions in matters of this kind, though temptingly easy to form, are not in the true scientific spirit, and act as a check upon careful research, which, by investigating the case in its various possible aspects, is able either to prove or disprove what otherwise would be merely a hasty assumption. The association of similar forms into the same series has therefore a double significance. On the one hand, the sequence of related forms is brought out, and their geographical distribution illustrated, throwing light, not only upon the evolution of types, but also upon the interchange of ideas by transferrence from one people to another, and even upon the migration of races. On the other hand, instances in which two or more peoples have arrived independently at similar results are brought prominently forward, not merely as interesting coincidences, but also as evidence pointing to the phylogenetic

unity of the human species, as exemplified by the tendency of human intelligence to evolve independently identical ideas where the conditions are themselves identical. Polygenesis in his inventions may probably be regarded as testimony in favor of the monogenesis of man.

I have endeavored in this address to dwell upon some of the main principles laid down by Colonel Lane Fox as a result of his special researches in the field of ethnology, and my object has been twofold. First, to bear witness to the very great importance of his contribution to the scientific study of the arts of mankind and the development of culture in general, and to remind students of anthropology of the debt which we owe to him, not only for the results of his very able investigations, but also for the stimulus which he imparted to research in some of the branches of this comprehensive science. Secondly, my object has been to reply to some criticisms offered in regard to points in the system of classification adopted in arranging his ethnographical collection. And, since such criticisms as have reached me have appeared to me to be founded mainly upon misinterpretation of this system, I have thought that I could meet them best by some sort of restatement of the principles involved.

It would be unreasonable to expect that his work should hold good in all details. The early illustrations of his theories were to be regarded as tentative rather than dogmatic, and in later life he recognized that many modifications in matters of detail were rendered necessary by new facts which had since come to light. The crystallization of solid facts out of a matrix which is necessarily partially volatile is a process requiring time. These minor errors and the fact of our not agreeing with all his details in no way invalidate the general principles which he urged, and we need but cast a cursory glance over recent ethnological literature to see how widely accepted these general principles are, and how they have formed the basis of, and furnished the inspiration for, a vast mass of research by ethnologists of all nations.

It appears more than probable that Cambridge will be much involved in the future advancement of anthropological studies in Great Britain, if we may judge from the evident signs of a growing interest in the science, not the least of which is the recent establishment of a board of anthropological studies, an important development upon which we may well congratulate the university. Within my own experience there have been many proofs of the existence in Cambridge of a keen sympathy with the principles of ethnological inquiry developed by Colonel Lane Fox, and I feel that, as regards my choice of a theme for the main topic of my address, no apology is needed. For my handling of this theme, on the other hand, I fear it must be otherwise. I would gladly have done fuller justice to the work of Colonel Lane Fox, but, while I claim to be among the keenest of his disciples, I must confess to being but an indifferent apostle.

I have been obliged, moreover, to pass over many interesting features in the work of this ingenious and versatile scientist. I have made no attempt to touch upon his archeological researches, since it has been necessary for me to restrict myself to a portion only of his scientific work. In this field, as in his ethnological work, his keen insight, ingenuity and versatility were manifested, while the close attention which he bestowed upon matters of minute detail has rendered classical his work as a field archeologist. While the greater part of his ethnological work is associated with the name Lane Fox, by which he was known until 1880, most of his researches into the remains of prehistoric times were conducted after he had in that year assumed the name of Pitt Rivers, on inheriting an important estate which, by the happiest of coincidences, included within its boundaries a considerable number of prehistoric sites of the highest importance. That he made full use of his opportunities is amply manifested in his published works. In his archeological work are repeated the characteristics of his ethnological researches, and one may with confidence say of his contributions to both fields of inquiry that, if he advanced science greatly through his results he furthered its progress even more through his methods. By his actual achievements as a researcher he pushed forward the base of operations; by his carefully-thought-out systems for directing research he developed a sound strategical policy upon which to base further organized attacks upon the unknown.

ON MOUNTAINS AND MANKIND.

By DOUGLAS W. FRESHFIELD,
PRESIDENT OF THE GEOGRAPHICAL SECTION OF THE BRITISH ASSOCIATION.

WE have all of us seen hills, or what we call hills, from the monstrous protuberances of the Andes and the Himalaya to such puny pimples as lie about the edges of your fens. Next to a waterfall, the first natural object (according to my own experience) to impress itself on a child's mind is a hill, some spot from which he can enlarge his horizon. Hills, and still more mountains, attract the human imagination and curiosity. The child soon asks, 'Tell me, how were mountains made?' a question easier to ask than to answer, which occupied the lifetime of the father of mountain science, De Saussure. But there are mountains and mountains. Of all natural objects the most impressive is a vast snowy peak rising as a white island above the waves of green hills—a fragment of the arctic world left behind to commemorate its past predominance—and bearing on its broad shoulders a garland of the Alpine flora that has been destroyed on the lower ground by the rising tide of heat and drought that succeeded the last glacial epoch. Mid-summer snows, whether seen from the slopes of the Jura or the plains of Lombardy, above the waves of the Euxine or through the glades of the tropical forests of Sikhim, stir men's imaginations and rouse their curiosity. Before, however, we turn to consider some of the physical aspects of mountains, I shall venture, speaking as I am here to a literary audience, and in a university town, to dwell for a few minutes on their place in literature—in the mirror that reflects in turn the mind of the passing ages. For geography is concerned with the interaction between man and nature in its widest sense. There has been recently a good deal of writing on this subject—I can not say of discussion, for of late years writers have generally taken the same view. That view is that the love of mountains is an invention of the nineteenth century, and that in previous ages they had been generally looked on either with indifference or positive dislike, rising in some instances to abhorrence. Extreme examples have been repeatedly quoted. We have all heard of the bishop who thought the devil was allowed to put in mountains after the fall of man; of the English scribe in the tenth century who invoked 'the bitter blasts of glaciers and the Pennine host of demons' on the violaters of the charters he was employed to draft. The examples on the other side have been comparatively neglected. It seems time they were insisted on.

The view I hold firmly, and which I wish to place before you to-day, is that this popular belief that the love of mountains is a taste, or, as some would say, a mania, of advanced civilization, is erroneous. On the contrary, I allege it to be a healthy, primitive and almost universal human instinct. I think I can indicate how and why the opposite belief has been fostered by eminent writers. They have taken too narrow a time limit for their investigation. They have compared the nineteenth century not with the preceding ages, but with the eighteenth. They have also taken too narrow a space limit. They have hardly cast their eyes beyond western Europe. Within their own limits I agree with them. The eighteenth century was, as we all know, an age of formality. It was the age of Palladian porticoes, of interminable avenues, of formal gardens and formal style in art, in literature and in dress. Mountains, which are essentially romantic and Gothic, were naturally distasteful to it. The artist says 'they will not compose,' and they became obnoxious to a generation that adored composition, that thought more of the cleverness of the artist than of the aspects of nature he used as the material of his work. There is a great deal to be said for the century; it produced some admirable results. It was a contented and material century, little stirred by enthusiasms and aspirations and vague desires. It was a phase in human progress, but in many respects it was rather a reaction than a development from what had gone before. Sentiment and taste have their tides like the sea, or, we may here perhaps more appropriately say, their oscillations like the glaciers. The imagination of primitive man abhors a void, it peoples the regions it finds uninhabitable with aery sprites, with 'Pan and father Sylvanus and the sister nymphs,' it worships on high places and reveres them as the abode of deity. Christianity came and denounced the vague symbolism and personification of nature in which the pagan had recognized and worshipped the unseen. It found the objects of its devotion not in the external world, but in the highest moral qualities of man. Delphi heard the cry 'Great Pan is dead!' But the voice was false. Pan is immortal. Every villager justifies etymology by remaining more or less of a pagan. Other than villagers have done the same. The monk driven out of the world by its wickedness fell in love with the wilderness in which he sought refuge, and soon learned to give practical proof of his love of scenery by his choice of sites for his religious houses. But the literature of the eighteenth century was not written by monks or countrymen, or by men of world-wide curiosity and adventure like the Italians of the renaissance or our Elizabethans. It was the product of a practical common-sense epoch which looked on all waste places, heaths like Hindhead, or hills like the Highlands, as blemishes in the scheme of the universe, not having yet recognized their final purpose as golf

links or gymnasiums. Intellectual life was concentrated in cities and courts, it despised the country. Books were written by townsmen, dwellers in towns which had not grown into vast cities, and whose denizens therefore had not the longing to escape from their homes into purer air that we have to-day. They abused the Alps frankly. But all they saw of them was the comparatively dull carriage passes, and these they saw at the worst time of year. Hastening to Rome for Easter, they traversed the Maurienne while the ground was still brown with frost and patched untidily with half-melted snowdrifts. It is no wonder that Gray and Richardson, having left spring in the meadows and orchards of Chambéry, grumbled at the wintry aspect of Lanslebourg.

That at the end of the eighteenth century a literary lady of western Europe preferred a Paris gutter to the Lake of Geneva is an amusing caricature of the spirit of the age that was passing away, but it is no proof that the love of mountains is a new mania, and that all earlier ages and peoples looked on them with indifference or dislike. Wordsworth and Byron and Scott in this country, Rousseau and Goethe, De Saussure and his school abroad broke the ice, but it was the ice of a winter frost, not of a glacial period.

Consider for a moment the literature of the two peoples who have most influenced European thought—the Jews and the Greeks. I need hardly quote a book that before people quarrelled over education was known to every child—the Bible. I would rather refer you to a delightful poem in rhyming German verse written in the seventeenth century by a Swiss author, Rebman, in which he relates all the great things that happened on mountains in Jewish history: how Solomon enjoyed his Sommerfrische on Lebanon, and Moses and Elias both disappeared on mountain tops; how kings and prophets found their help among the hills; how closely the hills of Palestine are connected with the story of the Gospels.

Consider, again, Greece, where I have just been wandering. Did the Greeks pay no regard to their mountains? They seized eagerly on any striking piece of hill scenery and connected it with a legend or a shrine. They took their highest mountain, broad-backed Olympus, for the home of the gods; their most conspicuous mountain, Parnassus, for the home of poetry. They found in the cliffs of Delphi a dwelling for their greatest oracle and a center for their patriotism. One who has lately stood on the top of Parnassus and seen the first rays of the sun as it springs from the waves of the Ægean strike its snows, while Attica and Bœotia and Eubœa still lay in deep shadow under his feet, will appreciate the famous lines of Sophocles, which I will not quote, as I am uncertain how you may pronounce Greek in this university. You may remember, too, that Lucian makes Hermes take Charon, when he

has a day out from Hell, to the twin-crested summit, and show him the panorama of land and sea, of rivers and famous cities. The Vale of Tempe, the deep gap between Olympus and Ossa, beautiful in its great red cliffs, fountains and spreading plane-trees, was part of a Roman's classical tour. The superb buttresses in which Taygetus breaks down on the valley of the Eurotas were used by the Spartans for other purposes besides the disposal of criminals and weakly babies. The middle regions—the lawns above the Langada Pass, 'virginibus bacchata Lacænis Taygeta'—are frequented to this day as a summer resort by Spartan damsels. The very top, the great rock that from a height of 8,000 feet looks down through its woods of oaks and Aleppo pines on the twin bays of the southern sea, is a place of immemorial pilgrimages. It is now occupied by a chapel framed in a tiny court, so choked with snow at the beginning of June that I took the ridge of the chapel roof for a dilapidated stoneman. I have no time to-day to look for evidence in classical literature, to refer to the discriminating epithets applied in it to mountain scenes.

A third race destined apparently to play a great part in the world's history—the Japanese—are ancient mountain lovers. We are all aware that Fusiyama to the Japanese is (as Ararat to the Armenians) a national symbol; that its ascent is constantly made by bands of pilgrims; that it is depicted in every aspect. Those who have read the pleasant book of Mr. Watson, who, as English chaplain for some years at Tokio, had exceptional opportunities of travel in the interior, will remember how often he met with shrines and temples on the summits of the mountains, and how he found pilgrims who frequented them in the belief that they fell there more readily into spiritual trances. The Japanese Minister, when he attended Mr. Watson's lecture at the Alpine Club, told us that his countrymen never climbed mountains without a serious—that is to say, a religious—object.

India and China would add to my evidence had I knowledge and time enough to refer to their literature. I remember Tennyson pointing out to me in a volume of translations from the Chinese a poem, written about the date of King Alfred, in praise of a picture of a mountain landscape. But I must return to the sixteenth and seventeenth centuries in Europe; I may go earlier—even back to Dante. His allusions to mountain scenery are frequent; his Virgil had all the craft of an Alpine rock-climber. Read Leonardo da Vinci's 'Notes,' Conrad Gesner's 'Ascent of Pilatus'; study the narratives of the Alpine precursors Mr. Coolidge has collected and annotated with admirable industry in the prodigious volume he has recently brought out.

It is impossible for me here to multiply proofs of my argument, to quote even a selection from the passages that show an authentic enthusiasm for mountains that may be culled from writers of various

nations prior to A. D. 1600. I must content myself with the following specimens, which will probably be new to most of my hearers.

Benoît Marti was a professor of Greek and Hebrew at Bern, and a friend of the great Conrad Gesner (I call him great, for he combined the qualities of a man of science and a man of letters, was one of the fathers of botany as well as of mountaineering, and was, in his many-sidedness, a typical figure of the renaissance). Marti, in the year 1558 or 1559, wrote as follows of the view from his native city:

"These are the mountains which form our pleasure and delight" (the Latin is better—'deliciæ nostræ, nostrique amores') "when we gaze at them from the higher parts of our city and admire their mighty peaks and broken crags that threaten to fall at any moment. Here we watch the risings and settings of the sun and seek signs of the weather. In them we find food not only for our eyes and our minds but also for our bellies"; and he goes on to enumerate the dairy products of the Oberland and the happy life of its population. I quote again this good man: "Who, then, would not admire, love, willingly visit, explore, and climb places of this sort? I assuredly should call those who are not attracted by them mushrooms, stupid, dull fishes, and slow tortoises" ('fungos, stupidos insulsos pisces, lentosque chelones'). "In truth, I cannot describe the sort of affection and natural love with which I am drawn to mountains, so that I am never happier than on the mountain crests, and there are no wanderings dearer to me than those on the mountains. They are the theater of the Lord, displaying monuments of past ages, such as precipices, rocks, peaks and chasms, and never-melting glaciers"; and so on through many eloquent paragraphs.

I will only add two sentences from the preface to Simler's 'Vallesiæ et Alpium Descriptio,' first published in 1574, which seems to me a strong piece of evidence in favor of my view: "In the entire district, and particularly in the very lofty ranges by which the Vallais is on all sides surrounded, wonders of nature offer themselves to our view and admiration. With my countrymen many of them have through familiarity lost their attraction; but foreigners are overcome at the mere sight of the Alps, and regard as marvels what we through habit pay no attention to."

Mr. Coolidge, in his singularly interesting footnotes, goes on to show that the books that remain to us are not isolated instances of a feeling for mountains in the age of the renaissance. The mountains themselves bear, or once bore, records even more impressive. Most of us have climbed to the picturesque old castle at Thun and seen beyond the rushing Aar the green heights of the outposts of the Alps, the Stockhorn and the Niesen. Our friend, Marti, who climbed the former peak about 1558, records that he found on the summit 'tituli, rythmi, et proverbia saxis inscripta unà cum imaginibus et nominibus

auctorum. Inter alia cujusdam docti et montium amœnitate capti observare licebat illud:

'Ο τῶν ὄρων ἔρως αριστος.'

'The love of mountains is best.' In those five words some Swiss professor anticipated the doctrine of Ruskin and the creed of Leslie Stephen, and of all men who have found mountains the best companions in the vicissitudes of life.

In the annals of art it would be easy to find additional proof of the attention paid by men to mountains three to four hundred years ago. The late Josiah Gilbert, in a charming but too little-known volume, 'Landscape in Art,' has shown how many great painters depicted in their backgrounds their native hills. Titian is the most conspicuous example.

It will perhaps be answered that this love of mountains led to no practical result, bore no visible fruit, and therefore can have been but a sickly plant. Some of my hearers may feel inclined to point out that it was left to the latter half of the nineteenth century to found climbers' clubs. It would take too long to adduce all the practical reasons which delayed the appearance of these fine fruits of peace and an advanced civilization. I am content to remind you that the love of mountains and the desire to climb them are distinct tastes. They are often united, but their union is accidental not essential. A passion for golf does not necessarily argue a love of levels. I would suggest that more outward and visible signs than is generally imagined of the familiar relations between men and mountains in early times may be found. The choicest spots in the Alpine region—Chamonix, Engelberg, Disentis, Einsiedlen, Pesio, the Grande Chartreuse—were seized on by recluses; the Alpine baths were in full swing at quite an early date. I will not count the Swiss Baden, of which a geographer, who was also a Pope, Æneas Silvius (Pius II.) records the attractions, for it is in the Jura, not the Alps; but Pfäfers, where wounded warriors went to be healed, was a scene of dissipation, and the waters of St. Moritz were vaunted as superseding wine. I may be excused, since I wrote this particular passage myself a good many years ago, for quoting a few sentences bearing on this point from 'Murray's Handbook to Switzerland.' In the sixteenth century fifty treatises dealing with twenty-one different resorts were published. St. Moritz, which had been brought into notice by Paracelsus (died 1541), was one of the most famous baths. In 1501 Matthew Schinner, the famous Prince Bishop of Sion, built 'a magnificent hotel' at Leukerbad, to which the wealthy were carried up in panniers on the back of mules. Brieg, Gurnigel, near Bern, the baths of Masino, Tarasp and Pfäfers were also popular in early times. Leonardo da Vinci mentions the baths of Bormio, and Gesner went there.

CORRELATION OF REFLEXES AND THE PRINCIPLE OF THE COMMON PATH.

BY PROFESSOR C. S. SHERRINGTON, M.A., D.SC., M.D., LL.D., F.R.S.,

PRESIDENT OF THE PHYSIOLOGICAL SECTION OF THE BRITISH ASSOCIATION.

PHYSIOLOGY studies the nervous system from three main points of view. One of these regards its processes of nutrition. Nerve-cells, as all cells, lead individual lives, breathe, dispense their own stores of energy, repair their own substantial waste, are, in short, living units, each with a nutrition more or less centered in itself. The problems of nutrition of the nerve-cell and of the nervous system, though partly special to this specially differentiated form of cell life, are, on the whole, accessible to the same methods as is nutrition in other cells and in the body as a whole.

But besides the essential functions common to all living cells, the cells of the nervous system present certain which are specialized. Among properties of living matter, one by its high development in the nerve-cell may be said to characterize it. I mean the cell's transmission of excitement spatially along itself and thence to other cells. This 'conductivity' is the specific physiological property of nerve-cells wherever they exist. Its intimate nature is, therefore, a problem co-extensive with the existence of nerve-cells, and enters as a factor into every question concerning the specific reactions of the nervous system.

Thirdly, physiology seeks in the nervous system how by its 'conductivity' the separate units of an animal body are welded into a single whole, and from a mere collection of organs there is constructed an individual animal.

This third line of inquiry, though greatly needing more data from the second and the first, must in the meantime go forward of itself. It is at present busied with many questions that seem special—hence its work is generally catalogued as special physiology. But it includes general problems. In the time before us I would venture to put before you one of these.

When we regard the nervous system as to this, which I would term its *integrative* function, we can distinguish two main types of system according to the mode of union of the conductors—(i.) the *nerve-net* system, such as met in medusa and in the walls of viscera, and (ii.) the *synaptic* system, such as the cerebro-spinal system of arthropods and vertebrates. In the integrative function of the nervous system the unit mechanism is the *reflex*. The chain of conduction in the reflex

is a nervous arc, running from a receptor organ to an effector organ, *e. g.*, from a sense-organ to a limb-muscle. We may still, I think, conveniently accept the morphological units termed neurones as units of construction of the reflex arc. It may be that these neurones are in some cases not unicellular, but pluricellular. That question need not detain us now. Accepting the neurone as the unit of structure of the reflex chain, the characteristic of the synaptic system is that the chain consists of neurones jointed together in such a way that conduction along the chain seems possible in one direction only. These junctions of the neurones are conveniently termed synapses. The irreversible direction of the conductivity along the neurone chain is probably referable to its synapses. This irreciprocity of conduction especially distinguishes the synaptic nervous system from the nerve-net system. That neurone forms the sole avenue which impulses generated at its receptive point can use whithersoever may be their distant destination. That neurone is therefore a path exclusive to the impulses generated at its own receptive points, and other receptive points than its own can not employ it.

But at the termination of every reflex arc we find a final neurone, the ultimate conductive link to an effector organ, gland or muscle. This last link in the chain, *e. g.*, the motor neurone, differs obviously in one important respect from the first link of the chain. It does not subserve exclusively impulses generated at one single receptive source alone, but receives impulses from many receptive sources situate in many and various regions of the body. It is the sole path which all impulses, no matter whence they come, must travel if they would reach the muscle fibers which it joins. Therefore, while the receptive neurone forms a private path exclusive for impulses of one source only, the final or efferent neurone is, so to say, a public path, *common* to impulses arising at any of many sources in a variety of receptive regions of the body. The same effector organ stands in reflex connection not only with many individual receptive points, but even with many various receptive *fields*. Reflex arcs arising in manifold sense organs can pour their influence into one and the same muscle. A limb muscle is the *terminus ad quem* of nervous arcs arising not only in the right eye, but in the left; not only in the eyes, but in the organs of smell and hearing; not only in these, but in the geotropic labyrinth, in the skin and in the muscles and joints of the limb itself and of the other limbs as well. Its motor nerve is a path common to all these.

Reflex arcs show, therefore, the general feature that the initial neurone is a private path exclusive for a single receptive point; and that finally the arcs embouch into a path leading to an effector organ, and that this final path is common to all receptive points wheresoever they may lie in the body, so long as they have any connection at all with

the effector organ in question. Before finally converging upon the motor neurone arcs usually converge to some degree by their private paths embouching upon internuncial paths common in various degree to groups of private paths. The terminal path may, to distinguish it from internuncial common paths, be called *the final common path.* The motor nerve to a muscle is a collection of such final common paths.

Certain results flow from this arrangement. One seems the preclusion of qualitative differences between nerve-impulses arising in different afferent nerves. If two conductors have a tract in common, there can hardly be qualitative difference between their modes of conduction.

A second result is that each receptor being independent for communication with its effector organ upon a path not exclusively its own, but common to it with certain other receptors, that nexus necessitates successive and not simultaneous use of the common path by various receptors using it to different effect.

The first link of each reflex chain is a neurone which starts in a receptor organ, *e. g.*, a sense-organ. A receptive field, *e. g.*, an area of skin, is always analyzable into receptive points, and the initial nerve-path in every reflex arc starts from a receptive point or points. A single receptive point may play reflexly upon quite a number of different effector organs. It may be connected through its reflex path with many muscles and glands in various parts. Yet all its reflex arcs spring from the one single shank, so to say; that is, from the one afferent neurone that conducts from the receptive point at the periphery into the central nervous organ. This neurone dips at its deep end into the great central nervous organ, the cord or brain. There it enters a vast network of conductive paths. In this network it forms manifold connections. So numerous are its potential connections there, that, as shown by the general convulsions induced under strychnia-poisoning, its impulses can discharge practically every muscle and effector organ in the body. Yet under normal circumstances the impulses conducted by it to this central network do not irradiate there in all directions. Though their spread over the conducting network does, as judged by the effects, increase with increase of stimulation of the entrant path, the irradiation remains limited to certain lines. Under weak stimulation of the entrant path these lines are sparse. The conductive network affords, therefore, to any given path entering it some communications that are easier than others. This canalization of the network in certain directions from each entrant point is sometimes expressed, borrowing electrical terminology, by saying that the conductive network from any given point offers less resistance along certain circuits than along others. This recognizes the fact that the conducting paths in the great central organ are arranged in a particu-

lar pattern. The pattern of arrangement of the conductive network of the central organ reveals somewhat of the integrative function of the nervous system. It tells us what organs work together in time. The impulses are led to this and that effector organ, gland or muscle, in accordance with the pattern. The success achieved in the unraveling of the conductive patterns of the brain and cord is shown by the diagrams furnished by the works of such investigators as Edinger, Exner, Flechsig, van Gehuchten, v. Lenhossek, v. Monakow, Ramon and Schäfer. Knowledge of this kind stands high among the neurological advances of our time.

But we must not be blind to its limitations. The achievement may, though more difficult, be likened to tracing the distribution of blood vessels after Harvey's discovery gave them meaning, but before the vasomotor mechanism was discovered. The blood vessels of an organ may be turgid at one time, constricted almost to obliteration at another. With the conductive network of the nervous system the temporal changes are even greater, for they extend to absolute withdrawal of nervous influence. Our schemata of the pattern of the great central organ take no account of temporal data. But the pattern of the web of conductors is not really immutable. Functionally its details change from moment to moment. In any active part it is a web that shifts from one pattern to another, from a first to a second, from a second to a third, then back perhaps to the first and then to a fourth and so on backwards and forwards. As a tap to a kaleidoscope, so a new stimulus that strikes the central organ causes it to assume a partially new pattern. The pattern in general remains, but locally the patterns are in constant flux of back and forward change. These time-changes offer, I venture to think, a study important for understanding the integrative function of the nervous system.

If we regard the nervous system of any higher organism from the broad point of view, a salient feature in its architecture is the following: At the commencement of every reflex arc is a receptive neurone, extending from the receptive surface to the central nervous organ.

INVENTION AND DISCOVERY.

By Hon. CHARLES A. PARSONS, M.A., F.R.S., M.Inst.C.E.,
President of the Engineering Section of the British Association.

On this occasion I propose to devote my remarks to the subject of invention.

It is a subject of considerable importance, not only to engineers, but also to men of science and the public generally.

I also propose to treat invention in its wider sense, and to include under the word discoveries in physics, mechanics, chemistry and geology.

Invention throughout the middle ages was held in little esteem. In most dictionaries it receives scant reference except as applied to poetry, painting and sculpture.

Shakespeare and Dryden describe invention as a kind of muse or inspiration in relation to the arts, and when taken in its general sense to be associated with deceit, as 'Return with an invention, and clap upon you two or three plausible lies.'

As to the opposition and hostility to scientific research, discovery and mechanical invention in the past, and until comparatively recent times, there can be no question, in some cases the opposition actually amounting to persecution and cruelty.

The change in public opinion has been gradual. The great inventions of the last century in science and the arts have resulted in a large increase of knowledge and the powers of man to harness the forces of nature. These great inventions have proved without question that the inventors in the past have, in the widest sense, been among the greatest benefactors of the human race. Yet the lot of the inventor until recent years has been exceptionally trying, and even in our time I scarcely think that any one would venture to describe it as altogether a happy one. The hostility and opposition which the inventor suffered in the middle ages have certainly been removed, but he still labors under serious disability in many respects under law as compared with other sections of the community. The change of public feeling in favor of discovery and invention has progressed with rapidity during the last century. Not only have private individuals devoted more time and money to the work, but societies, institutions, colleges, municipalities and governments have founded research laboratories, and in some instances have provided large endowments. These measures have increased the number of persons trained to scientific methods, and also

provided greatly improved facilities for research; but perhaps one of the most important results to engineers has been the direct and indirect influence of the more general application of scientific methods to engineering.

Sir Frederick Bramwell, in his presidential address to this association in 1888, emphasized the interdependence of the scientist and the civil engineer, and described how the work of the latter has been largely based on the discoveries of the former; while the work of the engineer often provides data and adds a stimulus to the researches of the scientist. And I think his remarks might be further appropriately extended by adding that since the scientist, the engineer, the chemist, the metallurgist, the geologist, all seek to unravel and to compass the secrets of nature, they are all to a great extent interdependent on each other.

But though research laboratories are the chief centers of scientific invention, and colleges, institutions and schools train the mind to scientific methods of attack, yet in mechanical, civil and electrical engineering the chief work of practical investigation has been carried on by individual engineers, or by firms, syndicates and companies. These not only have adapted discoveries made by scientists to commercial uses, but also in many instances have themselves made such discoveries or inventions.

To return to the subject, let us for a moment consider in what invention really consists, and let us dismiss from our minds the very common conception which is given in dictionaries and encyclopedias that invention is a happy thought occurring to an inventive mind. Such a conception would give us an entirely erroneous idea of the formation of the great steps in advance in science and engineering that have been made during the last century; and, further, it would lead us to forget the fact that almost all important inventions have been the result of long training and laborious research and long-continued labor. Generally, what is usually called an invention is the work of many individuals, each one adding something to the work of his predecessors, each one suggesting something to overcome some difficulty, trying many things, testing them when possible, rejecting the failures, retaining the best, and by a process of gradual selection arriving at the most perfect method of accomplishing the end in view.

This is the usual process by which inventions are made.

Then after the invention, which we will suppose is the successful attempt to unravel some secret of nature, or some mechanical or other problem, there follows in many cases the perfecting of the invention for general use, the realization of the advance or its introduction commercially; this after-work often involves as great difficulties and requires for its accomplishment as great a measure of skill as the inven-

tion itself, of which it may be considered in many cases as forming a part.

If the invention, as is often the case, competes with or is intended to supersede some older method, then there is a struggle for existence between the two. This state of things has been well described by Mr. Fletcher Moulton. The new invention, like a young sapling in a dense forest, struggles to grow up to maturity, but the dense shade of the older and higher trees robs it of the necessary light. If it could only once grow as tall as the rest all would be easy, it would then get its fair share of light and sunshine. Thus it often occurs in the history of inventions that the surroundings are not favorable when the first attack is made, and that subsequently it is repeated by different persons, and finally under different circumstances it may eventually succeed and become established.

We may take in illustration almost any of the great inventions of undoubted utility of which we happen to have the full history—for instance, of some of the great scientific discoveries, or some of the great mechanical inventions, such as the steam-engine, the gas-engine, the steamship, the locomotive, the motor-car or some of the great chemical or metallurgical discoveries. Are not most, if not all, of these the result of the long-continued labor of many persons, and has not the financial side been, in most cases, a very important factor in securing success?

The history of the steam-engine might be selected, but I prefer on this occasion to take the internal-combustion engine, for two reasons—firstly, because its history is a typical one; and secondly, because we are to hear a paper by that able exponent and great inventor in the domain of the gas-engine, Mr. Dugald Clark, describing not only the history, but the engine in its present state of development and perfection, an engine which is able to convert the greatest percentage of heat units in the fuel into mechanical work, excepting only, as far as we at present know, the voltaic battery and living organisms.

The first true internal-combustion engine was undoubtedly the cannon, and the use in it of combustible powder for giving energy to the shot is strictly analogous to the use of the explosive mixture of gas or oil and air as at present in use in all internal-combustion engines; thus the first internal-combustion engine depended on the combination of a chemical discovery and a mechanical invention, the invention of gunpowder and the invention of the cannon.

In 1680 Huygens proposed to use gunpowder for obtaining motive power in an engine. Papin, in 1690, continued Huygens's experiments, but without success. These two inventors, instead of following the method of burning the powder under pressure, as in the cannon, adopted, in ignorance of the thermodynamic laws, an erroneous course.

They exploded a small quantity of gunpowder in a large vessel with escape valves, which after the explosion caused a partial vacuum to remain in the vessel. This partial vacuum was then used to actuate a piston or engine and perform useful work. Subsequently several other inventors worked on the same lines, but all of these failed on account of two causes which now are very evident to us. Firstly, gunpowder was then, as it still is, a very expensive form of fuel, in proportion to the energy liberated on explosion; secondly, the method of burning the powder to cause a vacuum involves the waste of nearly the whole of the available energy, whereas, had it been burned under pressure, as in the cannon, a comparatively large percentage of the energy would have been converted into useful work. But even with this alteration, and however perfect the engine had been, the cost of explosives would have debarred its coming into use, except for very special purposes.

We come a century later to the first real gas-engine. Street, in 1794, proposed the use of vapor of turpentine in an engine on methods closely analogous to those successfully adopted in the Lenoir gas-engine of eighty years later, or thirty years ago. But Street's engine failed from crude and faulty construction. Brown, in 1823, tried Huygens's vacuum method, using fuel to expand air instead of gunpowder, but he also failed, probably on account of the wastefulness of the method.

Wright, in 1833, made a really good gas-engine, having many of the essential features of some of the gas-engines of the present day, such as separate gas and water pumps, and water-jacketed cylinder and piston.

Barnett, in 1839, further improved on Wright's design, and made the greatest advance of any worker in gas-engines. He added the fundamental improvements of compression of the explosive mixture before combustion, and he devised means of lighting the mixture under pressure, and his engine conformed closely to the present-day practise as regards fundamental details. No doubt Barnett's engine, so perfect in principle, deserved commercial success, but either his mechanical skill or his financial resources were inadequate to the task, and the character of the patents would seem to favor this conclusion, both as regards Barnett and other workers at this period. Up to 1850 the workers were few, but as time went on they gradually increased in number; attention had been attracted to the subject, and men with greater powers and resources appear to have taken the problem in hand. Among these numerous workers came Lenoir, in 1860, who, adopting the inferior type of non-compression engine, made it a commercial success by his superior mechanical skill and resources. Mr. Dugald Clerk tells us: "The proposals of Brown (1823), Wright (1833), Barnett (1838), Bansanti and Matteucci (1857), show gradually increasing knowledge of detail and the difficulties to be overcome, all leading to the first practicable engine in 1866, the Lenoir." This stage of the

development being reached, the names of Siemens, Beaude, Roches, Otto Simon, Dugald Clerk, Priestman, Daimler, Dowson, Mond and others appear as inventors who have worked at and added something to perfect the internal-combustion engine and its fuel, and who have helped to bring it to its present state of perfection.

In the history of great mechanical inventions there is perhaps no better example of the interdependence of the engineer, the physicist and the chemist than is evidenced in the perfecting of the gas-engine. The physicist and the chemist together determine the behavior of the gaseous fuel, basing their theory on data obtained from the experimental engines constructed by the mechanical engineer, who, guided by their theories, makes his designs and improvements; then, again, from the results of the improvements fresh data are collected and the theory further advanced, and so on till success is reached. But though I have spoken of the physicist, the chemist and the engineer as separate persons, it more generally occurs that they are rolled into one, or at most two, individuals, and that it is indispensable that each worker should have some considerable knowledge of all the sciences involved to be able to act his part successfully.

Now let us ask: Could not this very valuable invention, the internal-combustion engine, have been introduced in a much shorter time by more favoring circumstances, by some more favorable arrangement of the patent laws, or by legislation to assist the worker attacking so difficult a problem? I think the answer is that a great deal might be done, and I will endeavor to indicate some changes and possible improvements.

The history of this invention brings before our minds two important considerations. Firstly, let us consider the patentable matter involved in the invention of the gas-engine, the utilization for motive-power purposes of the then well-known properties of the explosive energy of gunpowder or of mixture of gas and oil with air. Are not these obvious inferences to persons of a mechanical turn of mind and who had seen guns fired, or explosions in bottles containing spirits of turpentine when slightly heated and a light applied to the neck? Surely no fundamental patent could have been granted under the existing patent laws for so obvious an application of known forces. Consequently, patent protection was sought in comparative details, details in some cases essential to success which were evolved or invented in the process of working out the invention. In this extended field of operations a slight protection was in some instances obtained. But in answer to the question whether such protection was commensurate with the benefits received by the community at large, there can, I think, be only one reply. Generally, those who did most got nothing, some few received insufficient returns, and in very few cases indeed can the return

be said to have been adequate. The second important consideration is that of the methods of procedure of the patentees, for it appears that very few of them had studied what had been suggested or done before by others before taking out their own patent. We are also struck by the number of really important advances that have been suggested and have failed to fructify, either from want of funds or other causes, to be forgotten for the time and to be re-invented later on by subsequent workers.

What a waste of time, expense and disappointment would be avoided if we in England helped the patentee to find out easily what had been done previously, on the lines adopted by the United States and German Patent Offices, who advise the patentee after the receipt of his provisional specification of the chief anticipatory patents, dead or alive! And ought we in England to rest content to see our patentees awaiting the report of the United States and German Patent Offices on their foreign equivalent specifications before filing their English patent claims? Ought not our Patent Office to give more facilities and assistance to the patentee?

Before proceeding further to discuss some of the possible improvements for the encouragement and protection of research and invention, I ask you to further consider the position of the inventor—the man anxious to achieve success where others have hitherto failed. To be successful he must be something of an enthusiast; and usually he is a poor man, or a man of moderate means, and dependent on others for financial assistance. Generally the problem to be attacked involves a considerable expenditure of money; some problems require great expenditure before any return can thereby accrue, even under the most favorable circumstances. In the very few cases where the inventor has some means of his own they are generally insufficient to carry him through, and there have unfortunately been many who have lost everything in the attempt. In nearly all cases the inventor has to cooperate with capital: the capitalist may be a sleeping partner, or the capital may be held by a firm or syndicate, the inventor in such cases being a partner—a junior partner—or a member of the staff. The combination may be successful and lasting, but unfortunately the best inventors are often bad men of business. The elements of the combination are often unstable, and the disturbing forces are many and active; especially is this so when the problem to be attacked is one of difficulty, necessitating various and successive schemes involving considerable expenditure, generally many times greater than that foreshadowed at the commencement of the undertaking. Under such circumstances, unless the capitalist or senior partner or board be in entire sympathy with the inventor or exercise great forbearance, stimulated by the hope of ultimate success and adequate returns, the case

becomes hopeless, disruption takes place, and the situation is abandoned. Further, in the majority of cases, after some substantial progress has been made it is found that under the existing patent laws insufficient protection can be secured, and the prospect of a reasonable return for the expenditure becomes doubtful. Under such circumstances the capitalist will generally refuse to proceed further unless the prospect of being first in the field may tempt him to continue.

Very many inventors, as I have said, avoid the expense of searching the patent records to see how far their problem has been attacked by others. In some cases the cost of a thorough search is very great indeed; sometimes it is greater than the cost of a trial attack on the problem. In the case of young and inexperienced inventors there sometimes exists a disinclination to enter on an expensive search; they prefer to spend their money on the attack itself. There are some, it is true, who have a foolish aversion to take steps to ascertain if others have been before them, and who prefer to remain in ignorance and trust to chance. It will, however, be said that the United States and German Patent Office reports ought to suffice to warn or protect the English patentee; but my own experience has been that such protection is not entirely satisfactory. There is, firstly, a considerable interval before such reports are received, and the life of a patent is short. Then, if the patent is upon an important subject, attracting general attention, the search is vigorous and sometimes overwrought, and the patent unjustly damaged or refused altogether. If, however, the patent is on some subject not attracting general attention, it receives too little attention and is granted without comment.

THE PROGRESS OF SCIENCE.

THE CAMBRIDGE MEETING OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

The meeting of the British Association at Cambridge was an event of sufficient scientific importance to deserve attention here as well as in Great Britain. We are pleased, therefore, to be able to devote the present number of the Monthly to it. President Pritchett, of the Massachusetts Institute of Technology, contributes an interesting account of the general features of the meeting. The address of the president of the association and of the president of the section of mathematics and physics are printed in full, and parts of other addresses are given. These addresses appear to give the best available survey of the range and problems of modern science. It is possible that some of them are in part too technical for the purposes of the general scientific reader, but he must meet the man of science half way. The difficulty is more in the terminology than in the ideas. When the pages are scattered over with statoliths and gametes there is a natural tendency to skip rather than to add to our usable vocabulary. But the entire terminology needed to understand the main results of modern science is not more difficult than one foreign language and not more extensive than that of the sporting field. The language of science should be acquired by people of intelligence, but at the same time men of science should learn on occasion to address those who are not specialists.

In addition to the presidential addresses before the sections, the British Association makes arrangements for several still more popular lectures, one addressed explicitly to 'working-men.' This lecture was given by Dr. J. E. Marr, of Cambridge, his subject being the 'Forms of Mountains.' Other lectures were given on 'Ripple Marks and Sand Dunes,' by Professor George Darwin; on 'The Origin and Growth of Cambridge University,' by Mr. J. W. Clark, and on 'Recent Paleontological Exploration,' by Professor H. F. Osborn, of Columbia University. On the other hand, the papers before the sections were mostly technical in character, though geography, anthropology, political science and education always give occasion for popular papers and discussions.

The entertainments and excursions at meetings of the British Association are always well arranged; it has indeed been urged that they are too attractive to camp followers. The social conditions in Great Britain are favorable to dinners and garden parties, and there is nearly always a duke or at least a lord ready to offer hospitalities. At Cambridge the entertainments were naturally academic in character, the principal functions being at Trinity and St. John's Colleges. Honorary degrees were conferred on some fifteen of the visitors, America being represented by Professor Osborn.

Cambridge proved to be an attractive place for the meeting, and no wonder, for a large part of the active British scientific workers have studied there, and the university unites scientific preeminence and medieval charm. The registration was 2,783, the sixth largest in the history of the association, and representing probably the largest gathering of scientific men. At Manchester and Liverpool, where the largest meetings have been held, the registration is swollen by local associates who pay the fees without taking

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HORACE LAMB, LL.D., F.R.S.

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much if any part in the sessions. The meeting next year will be in South Africa under the presidency of Professor George H. Darwin, who holds the chair of astronomy at Cambridge.

THE ADDRESS OF THE PRESIDENT.

It is as long as forty-two years since the association last met at Cambridge. There was a meeting at Oxford ten years ago after an interval of thirty-four years. The association was organized at York, in 1831, and held its second meeting at Oxford and its third meeting at Cambridge. It met again at Oxford in 1847 and 1860 and at Cambridge in 1845 and 1862. Some of the more conservative elements at the great universities have apparently not altogether welcomed the influx of visitors brought together by the diverse attractions of a meeting of the association. But if the meetings at the seats of the universities have not been frequent, they have tended to be of rather more than usual interest. The very contrast between the conservative and somewhat aristocratic attitude of the universities and the more radical and democratic aspects of the association have given an element of dramatic interest. Thus the Oxford meeting of 1860 is remembered for the invasion of the Darwinian theory. Bishop Wilberforce had been attacking the then infant theory in a superficial and rhetorical manner and is alleged to have turned to Huxley and asked him whether it was through his grandfather or his grandmother that he claimed his descent from a monkey. Huxley, after stating the case for evolution, said that a man has no reason to be ashamed of having descended from an ape, but that he would be ashamed to be related to a man who used his ability and position to obscure the truth. No wonder that it was thirty-four years before the association was again invited to meet at the home of 'lost causes and impossible loyalties,' nor is it surprising that it should then have been presided over by a great statesman, who once more attempted to discredit evolution and the Darwinian theory.

Now after ten years the association meets at the sister university, and is presided over by the nephew and successor as head of the British government of the president of the Oxford meeting. It is a strange sight as viewed from this land of magnificent levels. Mr. Balfour has character and abilities as notable and an intellect even more acute than had Lord Salisbury: there is a curious similarity in the attitude of the two men toward science, but at the same time an obvious forward movement in the authority of science when we pass from Oxford to Cambridge, from the older to the younger generation.

Lord Salisbury told his audience bluntly that he would make a survey 'not of our science but of our ignorance' and instanced atoms, the ether and the origin of life. He rejected natural selection and ended by appealing to the intelligent and benevolent design of an everlasting creator and ruler. Mr. Balfour is too acute a thinker to set natural selection and design in opposition to one another. He, indeed, takes natural selection for granted and uses it to discredit the possibility of knowledge. He tells us that natural selection working through utility could only give us the senses needed 'to fight, to eat and to bring up children,' not the intellect required to understand physical reality. The more successful we are in explaining the origin of our beliefs 'the more doubt we cast on their validity.' Mr. Balfour, however, is ready to sanction the newest theories of physical metaphysics, saying that down to five years ago 'our race has, without exception, lived and died in a world of illusions'; now apparently Mr. Balfour and a handful of physicists live in a real world of ether and electrical monads. But perhaps Mr. Balfour is a bit ironical, and is

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Professor of Chemistry, Trinity College, Dublin. President of the Chemical Section.

only poking fun at simple scientific folks. The outcome of the two addresses, clearly indicated in the one subtly implied in the other, is that our science having failed, we might as well accept the doctrines of the established church.

Mr. Balfour's address will be read with interest by all. The more difficult but very able address of Professor Lamb, also published in this number of THE POPULAR SCIENCE MONTHLY, should, however, be read in connection with it. As Professor Lamb tells us, science is justified by its results; we trust it because it honors our checks.

THE WORK OF THE SECTIONS.

THE British Association is divided into ten sections, which are at times subdivided. There were for example this year sub-sections for cosmical physics and for agriculture. The range of the British Association is somewhat wider than that of the American Association. Our association has recently established a section for experimental medicine, but this has not been active, whereas physiology at the British Association has one of the best sectional programs. We have no section for education and our section for political and social science is not very strong. These two sections are likely to offer papers and discussions that are only on the edge of science, but with the sections of geography and anthropology they give suitable entertainment to the 'general hearer,' whose cooperation in scientific work it should be one of the objects of such an association to secure.

The most interesting part of the program of Section A, and perhaps the most important discussion of the meeting from the scientific point of view, was that on the radio-activity of ordinary matter, in which Professor J. J. Thomson, Lord Kelvin, Lord Rayleigh and Sir Oliver Lodge took part, four physicists whose work can scarcely be paralleled in any other country. Professor Thomson, to whom the new theories in regard to matter are so largely due, described work that had been carried on in his laboratory. It has been found that metals give out radiations peculiar to each metal. This can scarcely be due to the presence of a small quantity of radium as it is constant with different samples of the same metal. Sir Oliver Lodge remarked that on the electric theory of matter all matter ought to be radio-active, and no atom of matter should be regarded as absolutely permanent. Perhaps it would not be going too far to say that the burden of proof rested with those who denied that ordinary matter was radio-active.

Physics is undoubtedly stronger in Great Britain than in the United States, and the Cavendish Laboratory at Cambridge has through the discoveries of Maxwell, Rayleigh and Thomson become the chief center for physical investigation in the world. It is natural, therefore, that this science should have been well represented at the recent meeting. Dr. Glazebrook, director of the National Physical Laboratory, described its work. He told of the part taken by the British Association in its establishment, described the scientific and technical work in progress and concluded by pleading for a larger measure of support. A table was submitted showing the amount of expenditure on buildings and equipment, and of the annual grant allowed for maintenance in similar institutions in various countries; this clearly demonstrated the unfortunate position in which the laboratory was placed, while the number of tests made and the receipts from applicants contrasted favorably with those of other nationalities.

Among other contributions of special interest was a paper by Professor J. A. Fleming on the propagation of electric waves along spiral wires and on an appliance for measuring the length of waves used in wireless telegraphy,

G. Brogi.

AUBREY STRAHAN, F.R.S.

District Geologist, Geological Survey of the United Kingdom. President of the Geological Section.

and an address by Professor J. H. Poynting on 'Radiation in the solar system.' A number of papers were presented to the section by foreign visitors including two by Professor Wood, of the Johns Hopkins University, one describing some recent improvements in the diffraction process of color photography and another on the anomalous dispersion of sodium vapor. Section A includes mathematics and astronomy as well as physics. Among the papers was one by Sir David Gill, director of the observatory at the Cape of Good Hope, entitled 'Problems of Astronomy,' which discussed some of the questions in practical astronomy now pressing for solution.

Before the Chemical Section Sir James Dewar gave an address on very low temperature phenomena with interesting demonstrations. He showed by a series of beautiful vacuum-tube experiments the behavior of nitrogen, oxygen, hydrogen and argon when submitted in contact with charcoal to the cooling influence of liquid air. The nitrogen tube exhibited the usual violet color when the spark passed through it, but as soon as the charcoal was immersed in the liquid air the tube passed through various stages of attenuated brilliancy until ultimately the vacuum became so high that the current could scarcely overcome the resistance. When the liquid air was removed the changes were passed through in the reverse order. Oxygen passed through a similar series of changes, but in the case of hydrogen the absorptive power of the charcoal at the temperature of liquid air was not great enough to render the tube non-conductive. Lord Kelvin, in proposing a vote of thanks to Professor Dewar, said that he was filled with expectation as to the condition of things that would be disclosed at a temperature of 5° absolute, where there would be no motion. What would become of electric conductivity, of magnetism, of thermal conductivity? He wished Sir James would continue his electro-conductivity experiments and bring him copper highly conductive at 8° but as great an insulator as glass at one or two or three degrees. Sir William Ramsay, speaking on the changes produced by the β-rays, said that he had obtained 105 milligrams of radium bromide, which, being too precious to risk in one vessel, were divided amongst three bulbs. These bulbs were placed in glass vessels, and were each provided with a tube to take away emanations. The vessels were colorless to start with, and were some of potash and some of soda glass, but in course of time the former became brown and the latter violet in color. The glass, too, became radio-active, but this property was removed by washing with water, although the color remained. When a solution of radium bromide was evaporated an invisible residue was left which was radio-active and dissolved to a radio-active solution. Radium formed chloride, sulphide, hydroxide and sulphate similar to lead, except that they were radio-active. The radium emanations rendered silver and platinum as well as glass radio-active. Professor W. O. Atwater, of Wesleyan University, presented two papers, one on the agricultural experimental work in the Smithsonian Institution and one on the experiments in nutrition carried out under his direction.

Mr. Aubrey Strahan's presidential address before the geological section was on earth movements, and this was taken as a subject for special discussion. In opening it Mr. Straham said that the subject proposed for discussion was the nature and origin of those movements of the earth's crust which have manifested themselves in the factoring, overthrusting and folding of strata. These movements have been in operation from the earliest to the latest geological periods; and, though they have been intermittent so far as any one region is concerned, there is reason to believe that they have been more or

Hills and Saunders.

Henry Balfour, M.A.

President of the Anthropological Section.

less continuously in action throughout the world as a whole. Their operations, in fact, are essential to the existence of a land surface, for in their absence all rocks projecting above the sea would be worn away, and the globe would become enveloped in one continuous ocean. Notwithstanding these facts, and though they have been the object of prolonged study, no theory as to the cause of the movements has commanded universal acceptance. While some hold that the shrinking of the globe by cooling and the efforts of the crust to adapt itself to the shrinking interior are the prime causes, others maintain that the scale on which folding and overthrusting in the crust have taken place is out of all proportion to the shrinking that can be attributed to such a cause. During the meeting the collections of fossils and rocks in the new Sedgwick Museum, adjoining the hall in which the section's proceedings took place, were open and largely visited by members.

Questions of heredity and experimental breeding were prominent in the proceedings of Section D as well as in the president's address. Exhibits were included, thus Miss Saunders showed a selection of stocks; Mr. Bateson, fowls and sweet peas; Mr. Darbishire, mice; Mr. Hurst, rabbits; Mr. Staples-Browne, pigeons; Mr. Doncaster, the Aleraxas moth; Mr. Locke, maize; and Mr. Biffers, wheat. Professor H. F. Osborn gave a lantern lecture on the evolution of the horse, and Professor J. C. Ewart and Professor W. Ridgeway described their investigations on the same subject. Professor Ewart's Celtic ponies, to which allusion was made, were on view in the court adjoining the Sedgwick Museum of Geology. Professor E. B. Poulton, of Oxford, delivered an address on the mimetic resemblance of Diptera for Hymenoptera, and Professor Gary N. Calkins, of Columbia University, one on the germ of smallpox. Other subjects having medical as well as strictly zoological interest were accounts of miner's worm and cancer research. Professor C. S. Minot, of Harvard University, read papers on regeneration, telegony and the Harvard embryological collection.

Before the Geographical Section there were several popular illustrated lectures, one on the work of the Scottish Antarctic Expedition, by Mr. W. S. Bruce, its leader; one by Mr. Silva White, on the unity of the Nile Valley, and one by Dr. Tempest Anderson, on the Lipari Islands and their Volcanoes.

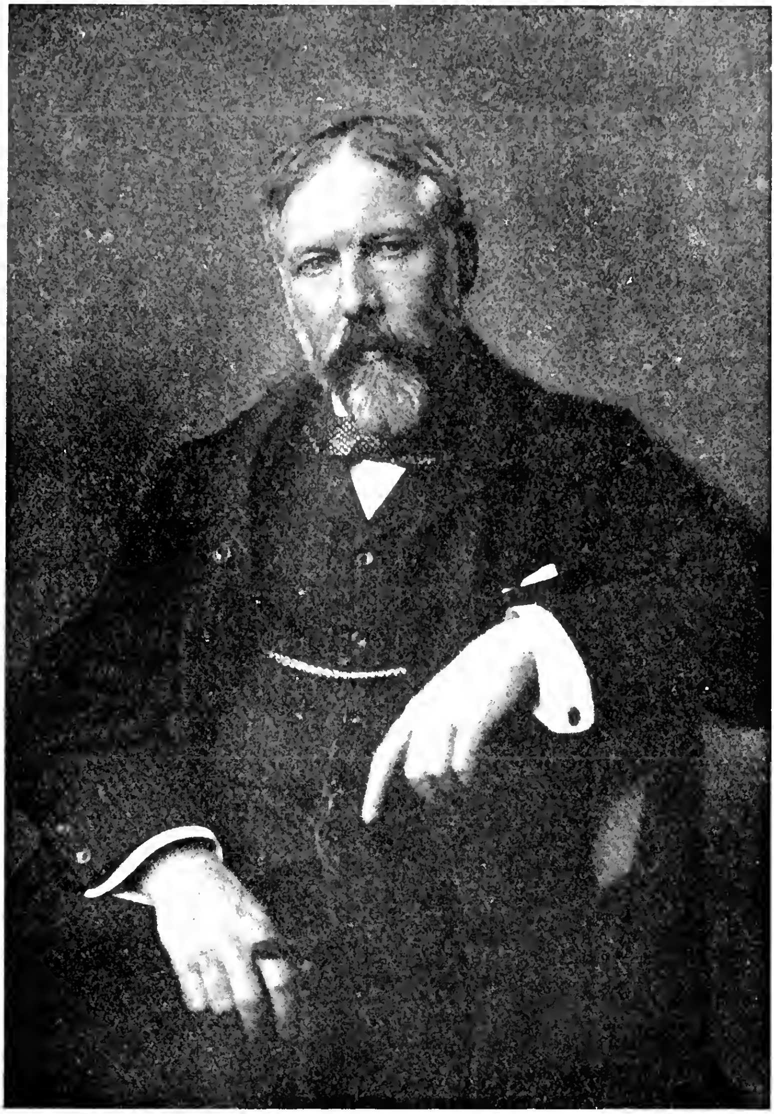
The next section in the alphabetical order, Economic and Social Science, also contained a good many popular addresses and papers. The topic for special discussion was the housing of the poor by municipalities, but free trade and protection were naturally prominent in view of the present national interests.

The sections for engineering and physiology were the most technical in the character of their discussions. In the latter Sir John Burdon-Sanderson opened an important discussion on oxidation and functional activity, or the relation between oxygen and the chemical processes of animal and plant life. Experimental psychology was included under physiology. In botany Professor H. Marshall Ward and Professor Jakob Eriksson, of Stockholm discussed recent work on the biology of the fungi, especially the uredineae, and Dr. F. F. Blackman gave an account of his experimental researches on the assimilation and respiration of plants. In a paper of general interest Lord Avebury discussed the forms of stems of plants, showing that they anticipated engineering work in the economical use of the strength of materials.

The establishment of a Section of Education has added considerably to the popular interest of the meetings. Among the subjects under discussion were school leaving certificates; the national and local provisions for the training of teachers, and manual instruction in schools. Discussions took place on the reports of committees; one


J. Caswall Smith.

DOUGLAS W. FRESHFIELD.
President of the Geographical Section.



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WILLIAM SMART, LL.D.

Adam Smith Professor of Political Economy, University of Glasgow. President of the Economic Science and Statistics Section.

on influence of examinations on teaching, and on the course of experimental, observational and practical studies most suitable for elementary schools, and one on conditions of health in schools.

A special session of the anthropological section was devoted to the question of an anthropometric survey of Great Britain and the alleged deterioration of the people. Mr. J. Gray outlined a plan that had been presented to the Privy Council committee according to which the United Kingdom would be divided into 400 districts, in each of which a representative sample of about 1,000 adults of each sex would be subjected to a large number of measurements and observations. The whole of the school children would be measured, because a thousand of each sex for each age interval of one year would be required, which would amount to about the whole of the school population. The survey would be completed once every ten years, and the total number measured in that time would be about 800,000 adults and 8,000,000 children. It is much to be hoped that the work of the Bureau of American Ethnology may be enlarged so that a similar survey may be made in the United States. Professor D. J. Cunningham and Dr. F. C. Shrubsall read papers, the latter discussing the relations of the blond and brunette types and the fact that the former tends to disappear in cities. Mr. Balfour, who presided over the meeting, remarked that the progeny of every man who won his way from the lowest ranks into the middle class was likely to diminish because of later marriages in that class. Hence it seemed that, as the state so contrived education as to allow this 'rising' from a lower to upper class, by so much did it do something to diminish the actual quality of the breed. It was, of course, not an argument against the state's attitude towards education in this respect; but there was, or seemed to be, no escape from the rather melancholy conclusion that everything done towards opening up careers to those of the lower classes did something towards the deterioration of the race.

In a survey such as this, it has of course only been possible to select from the programs and printed abstracts a few topics from the large number which came before the sections. They indicate, however, the general subjects now engaging the attention of scientific men and call to mind the names of a few of the leaders of science of Great Britain. It seems that on the whole the more eminent British men of science are more likely to attend the meeting of their general association and to take a part in its proceedings than is the case in this country, and it appears also that Great Britain has, at least in the physical sciences, more eminent men than we have.

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NAMES OF CONTRIBUTORS ARE PRINTED IN SMALL CAPITALS.

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VOL. LXV. No. 1 MAY, 1904

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EDITED BY J. McKEEN CATTELL

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THE SCIENCE PRESS

LANCASTER, PA. GARRISON, N. Y.

NEW YORK: SUB-STATION 84

SINGLE NUMBER, 30 CENTS YEARLY SUBSCRIPTION, $3.00

VOL. LXV. No. 2 JUNE, 1904

THE POPULAR SCIENCE MONTHLY

EDITED BY J. McKEEN CATTELL

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THE SCIENCE PRESS

LANCASTER, PA. GARRISON, N. Y.

NEW YORK: SUB-STATION 84

SINGLE NUMBER, 30 CENTS YEARLY SUBSCRIPTION, $3.00

The Popular Science Monthly

Entered in the Post Office in Lancaster, Pa., as second-class matter.

CONTENTS OF APRIL NUMBER

CONTENTS OF MAY NUMBER

PRESS OF THE NEW ERA PRINTING COMPANY.

Vol. LXV. No. 3 JULY, 1904

THE POPULAR SCIENCE MONTHLY

EDITED BY J. McKEEN CATTELL

CONTENTS

THE SCIENCE PRESS

LANCASTER, PA. GARRISON, N. Y.

NEW YORK: SUB-STATION 84

SINGLE NUMBER, 30 CENTS YEARLY SUBSCRIPTION, $3.00

VOL. LXV. No. 4 AUGUST, 1904

THE POPULAR SCIENCE MONTHLY

EDITED BY J. McKEEN CATTELL

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THE SCIENCE PRESS

LANCASTER, PA. GARRISON, N. Y.

NEW YORK: SUB-STATION 84

SINGLE NUMBER, 30 CENTS YEARLY SUBSCRIPTION, $3.00

The Popular Science Monthly

Entered in the Post Office in Lancaster, Pa., as second-class matter.

CONTENTS OF JUNE NUMBER

CONTENTS OF JULY NUMBER

PRESS OF THE NEW ERA PRINTING COMPANY.

VOL. LXV. No. 5 SEPTEMBER, 1904

THE POPULAR SCIENCE MONTHLY

EDITED BY J. McKEEN CATTELL

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THE SCIENCE PRESS

LANCASTER, PA. GARRISON, N. Y.

NEW YORK: SUB-STATION 84

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PRESS OF THE NEW ERA PRINTING COMPANY.

VOL. LXV. No. 6 OCTOBER, 1904

THE POPULAR SCIENCE MONTHLY.

EDITED BY J. McKEEN CATTELL

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THE SCIENCE PRESS

LANCASTER, PA. GARRISON, N. Y.

NEW YORK: SUB-STATION 84

SINGLE NUMBER, 30 CENTS YEARLY SUBSCRIPTION, $3.00

The Popular Science Monthly

Entered in the Post Office in Lancaster, Pa., as second-class matter.

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CONTENTS OF SEPTEMBER NUMBER

PRESS OF THE NEW ERA PRINTING COMPANY.